THE HISTORY OF THE TELEPHONE IN THE UNITED KINGDOM

F. G. C. BALDWIN

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HISTORY OF THE TELEPHONE IN THE UNITED KINGDOM

36 Coleman Street, London, E.C., the original home of the Telephone in London.

(From a photograph by Mr. H. J. Mobbs.)

[*Frontispiece*

THE HISTORY OF THE TELEPHONE IN THE UNITED KINGDOM

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FOREWORD

EVERY telephone man, and many others, will feel an immense debt of gratitude to Mr. Baldwin for this fine piece of research into the history of the telephone, primarily in this country, but with many sidelights on similar history in the United States. It must indeed have been no light task which he took up, and while it is likely that in such a multitude of detail there may well be some errors, yet I believe these are few and that a second edition will see them, if they exist, eliminated.

The history of the telephone is the history of a very important movement; man isolated and by himself is impotent and defenceless—in association with others of his kind, on the contrary, he is capable of much, and a primary condition for this association is communication. First, speech, limited to a few yards distance; then writing, which extended the distance while imposing a call for learning; then printing, with its facility for the increased distribution of communication; later telegraphy by visual signals, then the electric telegraph—virtually writing at a distance; then, from 1876, telephony gradually abolished the distance limitation to speech, so that now it is technically possible to construct telephone circuits over any land distance on the earth, and to operate them between centres of population at prices which people are willing to pay. Telephony has some of the properties both of the letter and of the newspaper; it can be clothed with privacy, given to one individual only, or it can be broadcast to millions simultaneously. Starting on a strictly local basis it spread until now it covers the whole country, and, extending still further, is beginning to develop into a system for intimate communication between individuals of different nationalities. The end is inevitable. Each system of any credit will have good communication between all its stations; there will also be good

communication between systems—hence any station on such system will be able to have speech with any other, bearing in mind that probably there will always be some stations which are not intended to have a radius of action of more than a very limited extent. But a great deal has yet to be done before this end is achieved as regards Europe, the immediate field. With so many nationalities responsible for the telephone service, the matter is one which has many political aspects, and these, if allowed to have undue influence, may well jeopardise the efficiency of the communication system. The technical men have been ready since the termination of the war; it remains for the business men to arrange an efficient organisation. When that has been effected there can be quick, reliable service given between all the centres of population in Europe desiring it. In the absence of an efficient organisation, a lame, inefficient, second-rate kind of service is all that can be expected; one in which the transmission is poor, the delays in completing connections are very long and many calls cancelled because of the delays; these are all marks of lack of grip in the International service; the price is a secondary matter, the really important things are accuracy, speed and quality. Upon how this organisation is worked out will depend the verdict upon the labours of the Consultative Committee for International Telephony in Europe.

But comparative telephone history has another aspect which is of interest and indeed of importance. It was a pioneer industry when it started; no one then knew if it would succeed. Would the public take to it? Would they continue to use it? What would be the cost of running it? All these questions and many more were at that time unanswered, and the men who risked their money and time in starting this pioneer business which was to prove of such immense value to mankind, had as backing, only that which they received from their faith; they got none from their country. Readers of this book will learn something, but not all, of the difficult and harassing conditions under which these pioneers worked, and will realise something of the reason for the backwardness of this country in the use of telephone service.

Some of the history of the telephone in the United Kingdom for the period 1904–1912 has not yet been written, perhaps never will be; but it is no reflection upon Mr. Baldwin's book that there

should be certain gaps in the history he narrates; these matters were known to few, and death has removed a number of those intimately concerned.

There is much in this book of great interest, but I think it has, to the student of social history, a value possibly even greater than to the student of telephony.

F. GILL.

LONDON,
February 1925

AUTHOR'S PREFACE

The acquisition by the State on January 1st, 1912, of the telephone systems of the United Kingdom, excepting the minor undertakings of the Hull and Portsmouth Corporations, marked a fitting stage at which the history of the telephone in this country might be chronicled. On that date, with the exceptions named, the administration of the telephone service became co-ordinated under single and uniform control for the whole of the country, and it is reasonable to suppose that subsequently all records pertaining to the development of telephony in the United Kingdom will be preserved in such form as to render the task of the historian, in matters telephonic, less difficult of accomplishment. Many in authority associated with the telephone service at the date mentioned were pioneers of, and were identified with telephony from its inception as a commercial project, and by reason of their lengthy and prominent association with the art, they were eminently fitted for the task of compiling a record of the most interesting work accomplished in the domain of telephony in this country between 1878 and 1912. So far, however, that history has not been forthcoming, and, lest the documentary and mental records at the present time available be lost beyond recall, I have attempted to remedy this omission by the preparation of this volume; it is in the hope that it may prove of interest, and perhaps of benefit, to present and future members of the telephone profession that the work has been entered upon.

The history of engineering has, it is feared, been somewhat generally neglected. The attention of the modern engineer is largely riveted upon the requirements of the present and of the future, and his time is fully occupied in the interests of mankind in pursuit of the improvement and perfection of the components of his profession. He has little or no time to devote to consideration of the things that are past, and there is, therefore, a

possibility that some of the processes, appliances and methods of working which have been but phases in the advancement of engineering science may be lost to future generations unless suitably recorded. Some may contend that the work of the past is done and that the need for revival of discarded methods and practices is unlikely to arise, but, nevertheless, it is surely true that a knowledge of the past history of any profession, industry or art is beneficial to the practitioner.

A knowledge of history is valuable largely because of the use to which it may be put in shaping prospective policy, in determining future methods and practice and in the avoidance of mistakes made in the past. The mistakes made in the realm of telephony have been far from negligible, and from this point of view alone the preparation of this volume may perhaps be justified.

Many of those to-day associated with the telephone service and industry are unfamiliar with the various phases through which telephony has passed, particularly in its infancy, and of the stages of technical development which have led up to the state of efficiency attained in the art of telephonic intercommunication at the present time, and to such, it is not improbable, that a knowledge of practice hitherto relegated to the oblivion of the past may prove of some use in the future.

So far as the United Kingdom is concerned, the entity of the telephone may be regarded as beginning in the year 1878, and therefore it has extended over a period of little more than forty-five years. In such a comparatively short time there might be reasonable justification for the supposition that the records essential to the construction of a complete history of commercial telephony still remain in existence, and that collection of the requisite data and compilation of the story would not be a matter presenting very much difficulty. This is not altogether the case, however, particularly in regard to technical matters. During the nine years' *régime* of the United Telephone Company, when the master patents were in force, due in a large measure to the patent situation and the legal considerations arising out of the possibilities of infringement, an atmosphere of extreme conservatism and exclusiveness appears to have been created, which was not dissipated for a very long time. The policy adopted by the United Telephone Company was exemplified by the fact that

officers of that company were even denied the privileges accruing from membership of the Institution of Electrical Engineers, and were actually forbidden even to attend its meetings. Consequently, during the time the United Telephone Company operated, that is, from 1880 to 1889, the dearth of telephone technical publications was particularly marked, and it is only in comparatively late years that the subject of telephony has begun to assume its rightful place in technical literature, and in the deliberations of institutions which exist for the advancement of engineering science.

Through the instrumentality of several interested parties, there has fortunately been preserved a quantity of telephone apparatus of considerable historic interest. The National Telephone Company's accumulation of historic telephone instruments, etc., was, in 1912, added to a similar collection gathered together by the Post Office, and the two are still preserved at the General Post Office, London. At the Science Museum, South Kensington, maintained under the auspices of the Board of Education, there is a most interesting exhibit of telephone, as well as of telegraph, appliances and parts derived from various sources. A list of those items comprised in the telephone section appears in Appendix E. Included in an historic collection of electrical plant of various descriptions, at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C. 2, is a series of most interesting specimens of telephone transmitters, receivers, complete instruments and other accessories, also detailed in the Appendix.

Many items represented in the aforementioned collections are referred to in the following pages, and the student of telephone history may profitably spend some time upon their inspection and examination.

Considerable thought has been given to the arrangement of the various chapters of this work, with a view to the presentation, as far as possible, of a connected narrative, the division of the subject into suitable subheads, and the avoidance of overlapping and repetition. Chapters I, II, and III follow consecutively in datal order, but thereafter, subdivision has been deemed necessary, and the commercial and several technical aspects of telephony are dealt with in separate chapters. London and the Provincial

towns have to a certain extent been treated apart. A separate chapter, No. XXI, has been devoted to the question of legislation, a factor which has exercised such an important influence upon telephone development in this country. Municipal telephony, a distinct phase in the telephoning of the United Kingdom and more or less a side issue, is also treated independently in Chapter XIV. Telephone switching methods and appliances are dealt with for the most part in separate chapters, and Chapter XX is entirely devoted to consideration of the introduction and development of automatic or machine switching systems. The importance and complexity of telephone switching have led to the subject being given a prominent place in most technical works on telephony, but scant attention has usually been given to the question to Distribution, no less consequential in view of the important financial and economic considerations involved; therefore a separate chapter, No. XIX, has been devoted to that subject.

Information has been drawn from such numerous sources that it is impracticable to mention them all, but specific reference should be made to the following journals and technical works, which have contributed in various ways to the pages of this volume, some of them not being mentioned in the text :—

The Electrician.
The Electrical Review.
The Electrical Engineer.
Electrical Engineering.
The Post Office Electrical Engineers' Journal.
The National Telephone Journal.
The Telegraph and Telephone Journal.
Journal of the Institution of Electrical Engineers.
"Posts and Telegraphs," by William Tegg, 1878.
"The Electric Telegraph," by Dr. Lardner and Ed. B Bright, F.R.A.S., 1867.
"The Telegraph Manual," by Tal. B. Shaffner of Kentucky, 1859.
"A Manual of Telephony," by W. H. Preece and J. Maier.
"The Practical Telephone Handbook," by J. Poole.
"Manual of the Telephone," by W. Aitken.

"A Manual of Telegraph Construction," by John Christie, 1877.

"The Telephone, The Microphone and The Phonograph," by Count du Moncel, 1879.

Many of my friends and acquaintances who were intimately associated with or interested in early telephone development, and others with whom acquaintance has been made during the search for information, in the endeavour to make this volume as complete as possible, have very generously placed all the records they possessed at my disposal and also have most kindly, and at some difficulty and inconvenience to themselves, summoned their recollections to aid in the construction of the telephone story. When brought to play over such a lengthy proportion of man's allotted span of existence as is embraced by telephone history, memory, however, is apt to be fickle, and therefore, unconsciously, I may be guilty of presenting information which is open to criticism. Every possible effort has, nevertheless, been made to avoid doubtful statements without qualification, and to render the work as free from inaccuracies as possible.

I wish to tender my warmest thanks to all those who have so generously assisted in the preparation of this volume, by the collection and supply of information, and the gift or loan of photographs and apparatus for purposes of illustration. I should especially mention Mr. Gill, whose foreword I much appreciate, Mr. E. S. Byng, of the Western Electric Company, for ungrudging assistance rendered in many directions, the late Mr. J. W. Ullett, of Nottingham, for the loan of a valuable selection of photographs and documents of historic interest, and for his recollections of early telephone history in London; Mr. F. W. Best, of Rochdale, for his untiring efforts in search of information, and for the gift of a number of pieces of apparatus, photographs of which appear in their proper place, and Mr. J. R. M. Elliott and Mr. H. Kitchen for generous assistance in various ways. I am also indebted to Mr. J. E. Kingsbury for his permission, so willingly given, to make use of information from his book "The Telephone and Telephone Exchanges," from which I have freely drawn, and to Mr. C. Whillis, of Newcastle-on-Tyne, for great assistance with the manuscript.

Much information concerning the activities and engineering practice of the British Post Office is included, and I desire also to express my indebtedness and thanks to Colonel Purves, O.B.E., M.I.E.E., Engineer-in-Chief to the Post Office, for permission to publish the matter in question.

I have endeavoured to avoid failure to make mention in the appropriate place of the numerous gentlemen to whom I am beholden in various ways. Lest, however, through oversight any name or source of information has been omitted, I desire to take this opportunity of expressing my apologies.

F. G. C. Baldwin.

Wylam-on-Tyne,
December 1924.

ERRATA

Page 255, line 9, *for* 1918 *read* 1898.

Page 463, line 4 from foot, *for* R. Shepherd *read* G. M. B. Shepherd.

Page 645, line 1, *for* Western Electric *read* American Telephone and Telegraph.

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HISTORY OF THE TELEPHONE IN THE UNITED KINGDOM

CHAPTER I

INVENTION OF THE TELEPHONE BY GRAHAM BELL AND ITS INTRODUCTION INTO ENGLAND, 1876–1878

MAN has been endowed by nature with means for carrying on mutual intercourse, and, irrespective of philological considerations, so long as the organs of speech and hearing perform their functions properly interchange of speech is possible.

Such intercourse can, however, only be conducted within the limiting distance over which oral sounds can be perceived, and, almost ever since the world began the problem of conducting communication over distances beyond the natural limits has exercised the mind of man.

The transmission of actual speech, or more correctly the reproduction of speech over long distances by means of the telephone, has only been made possible within the past 45 years, a very brief span indeed in the history of the world, and many other measures for the transmission of intelligence between point and point had previously been devised and practised from time to time. Up to the time of the introduction of the telegraph, communication over appreciable distances was necessarily laboured and slow, and all the methods adopted, including the telegraph, involved the conversion of the intelligence to be communicated into signs or symbols, which again had to be retranslated when received.

It is not intended to trace in detail the history of "Communication" prior to the introduction of the telephone, but brief mention should perhaps be made of some of the experiments which were made and the chief means which were employed towards the establishment of communication at a distance.

The first messages were no doubt conveyed in symbolic or in written form by means of runners, messengers or couriers of which one may frequently read in Biblical and other history, and signals of various forms were devised and utilised.

In this country beacons, usually in the form of fires kindled in prominent positions, were frequently utilised as signals and, as every schoolboy learns, and as related in Lord Macaulay's unfinished and well-known poem "The Spanish Armada," in 1588, a chain of beacon fires flashed to various parts of this country the news of the approach of the Spanish Armada.

A regular system of postal communication was first established in this country in 1603, the mails being carried by special messengers mounted on horseback; the mail coach became the recognised means of conveyance of mails in 1785.

The Bellman or Town Crier is a well known and not yet entirely extinct means of distributing common intelligence to townspeople.

In 1668–1671 the speaking trumpet for augmenting the sounds transmitted, and the ear-trumpet for increasing the audibility of sounds received, appear to have been first constructed with the object of increasing the distance over which sounds might be sent through the atmosphere. The speaking trumpet was chiefly intended for use at sea, and was the prototype of the present-day megaphone.

Signals transmitted by the aid of flags and semaphores followed. These had a greater range than the speaking trumpet, but possessed the disadvantages of the introduction of a code, and of being unusable at night and in other than clear weather.

The French appear to have been the pioneers of semaphore signalling, introduced into this country in 1840, when a line of semaphores was erected between Deal and London for use by the Admiralty. The chain of communication consisted of a series of towers, adjacent ones being within sight of each other. The letters of the alphabet were represented by an arrangement of distinct formations of six octagonal frames, and when the atmosphere was clear a short message could be transmitted from one place to the other in the course of a few minutes.

In the period 1774 to 1837 numerous scientists and physicists of various nationalities were engaged in the pursuit of an electrical

means of communication, which culminated, in the latter year, in the practical application of the first form of needle telegraph by Sir Charles Wheatstone and William Fothergill Cooke.

Sir Charles Wheatstone, who made his name famous in the realm of telegraphy, as well as in other directions, devised and practised, in 1821, a method of transmitting music by means of a series of wooden rods which served as the medium by which the sound was conveyed. Wheatstone's idea was based upon the molecular vibration set up in solid bodies by sound, and his device, which was utilised as a novelty, was referred to in the " Repository of Arts " for September 1821.

First use of the word " telephone " has been generally ascribed to Wheatstone in describing this apparatus for transmission of sound by molecular vibration, but the accuracy of this appears to be in some doubt. It is true that Wheatstone used the word no later than 1840, and it is highly probable that the term did originate with him. The word " Telephone " is derived from the Greek, " tele " and " phone," respectively meaning, " at a distance " and, " sound."

In the December issue of the *National Telephone Journal* for 1908 an extract is given from the *Illustrated London News* of August 24th, 1844, wherein is described and illustrated a contrivance termed " The Telephone, A Telegraphic Alarum." This apparatus, invented by Capt. J. N. Taylor, R.N., was for the purpose of conveying signals at sea by means of sound produced by the passage of compressed air through a pipe or trumpet, containing a steel reed. The air was compressed by turning a handle by hand and four keys were provided, by depression of which four distinct notes could be obtained. It was claimed that by means of this device signals could be conveyed for a distance of four or five miles.

The speaking tube was much used for conveying speech from one point to another in residences, offices, workshops, hotels, etc., before the telephone came into general use for short distance communication. It appears to have been introduced generally in 1851, but its origin is, no doubt, anterior to this date.

As early as 1667, Robert Hooke, an English mathematician and natural philosopher, who, incidentally, was responsible for the invention of the balance spring of watches (usually ascribed to Huygens, the Dutch physicist), described how, by means of a

tightly stretched wire, sound could be transmitted over a considerable distance. His idea appears to have been the origin of the so-called " String Telephone," and, if this assumption be correct, it was revived with the introduction of that device in 1860. For some years the " String Telephone " was a familiar toy. It consisted essentially of two similar cylindrical boxes without lids, the bottom of each being formed by a piece of tightly stretched parchment to serve as a diaphragm. The two ends of a long string were secured respectively to the centre points of the parchment diaphragms. On the string being maintained taught, faint conversation could be carried on by virtue of the vibration of the string, the two parchment covered boxes being used alternately as receiver and transmitter.

It will have been gathered from the foregoing pages that the idea of transmitting sound to a distance is evidently one of considerable antiquity and that during a period which embraced at least three centuries the subject received attention by various physicists and experimenters. The methods they adopted were dependent upon the use of air or solid bodies for the direct transmission of the vibrations propagated by sound.

In none of the attempts to solve the problem of the transmission of sound over long distances which have been mentioned was the employment of electricity considered, and it was not until 1876–1878 that the transmission of articulate speech by electrical means was satisfactorily accomplished. It was left to Professor Graham Bell, of Boston, U.S.A., to produce the first practical form of telephone, and to him mankind is indebted for the benefits which the telephone has bestowed, in providing means for communicating over long distances directly by interchange of speech.

Graham Bell's telephone was dependent for its action upon electro-magnetic induction, a phenomenon observed 45 years prior to the publication of his invention. In this period, and in the earlier part of the nineteenth century remarkable developments in electrical science occurred.

The purpose of this volume is to portray concisely the history of the telephone as a practical proposition in the United Kingdom, and therefore no attempt will be made to describe in detail the work accomplished by those who, at one time or another, had laboured in the same broad field of investigation as its

inventor. In order, however, that the practical telephone of Graham Bell, which so quickly developed in such a remarkable way, may be suitably connected with the work of those who preceded him, it will perhaps be well briefly to review the principal experiments and discoveries which paved the way to Graham Bell's wonderful invention.

In 1819, Hans Christian Oersted of Copenhagen discovered the influence which a voltaic current exerted upon a magnetic needle, and he established the relationship which existed between the direction of the current and the direction of movement of the needle. With this discovery of Oersted the knowledge of electro-magnetism began, and as the practical telephone was essentially a magneto electric device the history of the telephone may very appropriately be said to commence from this date.

In 1820, Sir Humphry Davy, a distinguished English chemist, and Francois Jean Arago, a French physicist, independently discovered that iron and steel rods or needles became magnetised under the influence of an electric current circulating round a spiral of copper wire which encircled them.

William Sturgeon made the first really practical use of Sir Humphry Davy's discovery, and in 1825, Sturgeon constructed electro-magnets of much greater power than those previously made. He it was who first made an electro-magnet of horse-shoe shape, and who introduced the term "electro-magnet."

Michael Faraday, one of the greatest of English chemists and physicists, was born in 1791. It was largely due to the influence of Sir Humphry Davy that the great Faraday entered seriously upon the study of physics. Faraday's exhaustive work led to numerous discoveries which have been of benefit to mankind; amongst these was one, made in 1831, that electric currents might be induced in a closed circuit by the motion of a magnet in its immediate vicinity, and, conversely, by moving the circuit across the magnetic field; in other words, Faraday discovered the phenomenon of electro-magnetic induction upon which Bell's telephone was dependent for its action. Michael Faraday died on August 25th, 1867.

The transformation of electrical energy into magnetic and the conversion of magnetic energy into electric are the two most important principles in the whole realm of electric science. They constitute the basis which underlies electrical operations of every

class, including power generation, telegraphy and telephone communication.

Joseph Henry of New York, the inventor of the telegraph sounder, whose name has been fittingly identified with the work which he accomplished, by its universal adoption to represent the unit of inductance, carried out investigations in electro-magnetic induction and he demonstrated the difference in effect of an electro-magnet with a few turns of wire and one in which many turns of fine wire were used. Henry thus showed how to construct an electro-magnet capable of being operated over a great length of wire.

Professor Charles G. Page, of Salem, Mass., discovered in 1837 that, at the moment when a bar of steel is magnetised or demagnetised, a faint metallic click may be heard. This he designated the "Magnetic Tick." He also found that when the magnetisation and demagnetisation of an iron bar was effected at a sufficiently rapid rate, a musical note was obtained, which he called "Galvanic Music."

In 1843, De la Rive, of Geneva, followed up Page's investigations and, by utilising long iron wires, passing through coils of insulated wire, he increased the effect obtained by Page.

Charles Boursel, a Frenchman, published, in 1854, a paper on the electric transmission of speech, and he announced that delicate experiments which he had made, requiring time and patience, gave promise of a favourable result. He generally prognosticated the early transmission of speech by electrical means. He does not, however, appear to have pursued the matter any further.

In 1861, Phillip Reis, a German electrician of Friedrichsdorf, adapted the idea of Page, previously mentioned, in the apparatus which he termed a telephone and which he exhibited to the Physical Society of Frankfort-on-Main in the same year. He succeeded in transmitting by electrical means musical and other sounds. His transmitter comprised a point of loose contact in an electrical circuit, so arranged that the resistance of the circuit was varied according to the intimacy of contact between the two points (which were of platinum), one of them being mounted upon a membrane or diaphragm upon which the sound waves to be transmitted were caused to impinge. Reis made use of the Page effect in his receiver which consisted practically of

the apparatus Page used to demonstrate the so called " Magnetic Tick," viz., an iron rod within a coil of insulated wire mounted upon a sounding board. Although Reis's instrument was a near approach to a satisfactory speaking telephone, with variable resistance transmitter and magnetic receiver, it seems highly probable that Graham Bell's invention was made quite independently.

Messrs. Cecil and Leonard Wray endeavoured to improve the apparatus devised by Reis with the intention of intensifying the effect.

Hermann-Ludwig Ferdinand Helmholtz, a German physiologist and physicist, one time Professor of Physics at Berlin, carried out numerous experiments about 1863 relative to the analysis of speech and the reproduction of sound. In connection with some of his experiments, he attempted artificially to produce various vowel sounds, using an arrangement of tuning forks maintained in vibration by means of electro-magnets and a battery. These experiments were subsequently repeated by Graham Bell, who was much interested in the idea of causing one tuning fork to vibrate in unison with another, by means of an interrupted electric current.

Mr. Kempster B. Miller, in his treatise on " American Telephone Practice," mentions that, in 1868, Royal E. House, of Binghampton, New York, invented and patented an instrument termed an " Electro-phonetic Telegraph," which was capable of operating as a magneto telephone, in the same manner as the instruments subsequently devised by Bell. An illustration of the apparatus appears in Mr. Miller's book. House knew nothing of its capabilities, however. The instrument was provided with a diaphragm of varnished pine, mounted at one end of a large sound amplifying chamber, so formed as to focus the sound waves at a point near its mouth, where the ear was placed to receive them. To the centre of the wooden diaphragm one end of a rod was secured; the other end of the rod was affixed to the armature of an electro-magnet with coils included in the line circuit. Movement imparted to the diaphragm by impinging sound waves was thus communicated to the armature and corresponding currents were induced in the line; as a receiver, movements of the armature caused by received currents were transmitted to the diaphragm and corresponding sounds were emitted.

A harmonic telegraph was devised in 1870 by Cromwell Fleetwood Varley, who experimented with tuning forks; the vibrating tuning forks were caused to make and break an electric circuit in a manner similar to that practised by Helmholtz in connection with his investigations in the analysis of sound.

On February 12th, 1877, musical sounds were transmitted between two London theatres.

Samuel Alfred Varley constructed a telephone receiver in the form of a condenser; the rapid charge and discharge of the device gave rise to musical notes and articulate speech.

Messrs. Pollard and Garnier eventually simplified the condenser telephone and exhibited and worked, in London, an apparatus which consisted of a " singing condenser " and a form of carbon transmitter associated with an induction coil. This device created much interest in London at the time.

The contributions which were made towards the production of the telephone were many and varied. Some of them without doubt Graham Bell made use of, others he may have unconsciously copied, but the fact remains that Graham Bell was the first to produce, and make known publicly, an instrument which transmitted articulate speech and other sounds, and to carry it to a successful conclusion.

For fuller information and details of the investigations and experiments carried out preparatory to the invention of the telephone, reference should be made to the various text-books and other works which deal with this aspect of the subject.

At the time his invention was proclaimed Alexander Graham Bell resided in the city of Boston, U.S.A. He was, however, by birth a Scotsman, Edinburgh being his native city. He received his early education at the Royal High School, but in 1870, accompanied his father, who left this country on account of his son's health, and took up residence near Brantford, Ontario, where his early experiments were conducted, a fact which has gained for it the name of " The Telephone City." Graham Bell's father was Alexander Melville Bell, of Edinburgh and London, a professor of elocution, who gained eminence by his scientific analysis of the elements of speech. Under his father's direction and encouragement, Graham Bell in his early days studied acoustics as applied to the subject of speech, thus following to some extent the vocation of his father.

After studying the works of Helmholtz, for the express purpose of experimenting in the production of vowel sounds by artificial means, he commenced the study of electricity and amongst other things he repeated Helmholtz's experiment with the vibrating tuning forks, with which he appears to have been much impressed.

He became acquainted with Sir Charles Wheatstone in his younger days, and no doubt gained from him knowledge of the science of acoustics.

In 1872, Graham Bell removed to Boston, and there received as pupils deaf mutes and those whose speech was defective, and did much in the cause of those who were so afflicted.

The honorary degree of LL.D. was bestowed upon Graham Bell by the Edinburgh University on April 12th, 1906, and on December 2nd, 1920, while on a visit to this country, he was presented with the freedom of that city.

During the course of his investigations Graham Bell conducted some experiments at the Boston Institute of Technology and by means of a phonautograph which had been improved by Mr. Maurey, a student at the Institute, secured some interesting results. The improvement referred to consisted of a long stylus of wood attached to the membrane of the instrument, and by its means Graham Bell was successful in producing some stylo-graphs of the vowel sounds. It is interesting to contrast these tracings with modern oscillographs of similar sounds. Some of them are reproduced in Count Du Moncel's work on "The Telephone."

It is not proposed to enter into a detailed description of the experiments which Graham Bell conducted or of the various stages through which his invention passed before he produced a really practical instrument. Suffice it to say that his close application to the problem extended over a period of about four years, *i.e.*, from 1872 to 1876. For details of his researches and particulars of the various models he made before he arrived at a satisfactory solution of the problem reference should be made to the several publications dealing with the subject. Count du Moncel's work on "The Telephone, the Microphone and the Phonograph," published in this country in 1879, and a more recent work by J. E. Kingsbury, entitled, "The Telephone and Telephone Exchanges," published in 1915, give exhaustive information in this connection.

It should be made clear that the production of the telephone

was not entirely due to an accidental discovery or spontaneous conception, rather was it the result of the extended labours of various physicists, of which Graham Bell was able to avail himself, combined with his own assiduous study of the science of acoustics. Graham Bell's application to the problem of the reproduction of speech by electrical means was largely due to the early influence of his father, who instilled into the mind of his son a fervour for his own studies and work.

Although Graham Bell conceived the idea of and deliberately strove for the production of the speaking telephone, it was nevertheless due to a happy accident or discovery that he was directed to the right path which led him ultimately to accomplish the transmission of sound to a distance by electrical means.

Some time before the production of his speaking telephone Graham Bell had perceived the rudiments of the principle upon which the electrical transmission of sound might be based, and he is reported to have pronounced the theory that if a current of electricity could be varied in intensity precisely as the air varies in density during the production of sound, speech might be transmitted telegraphically. At the time the telephone was invented, Graham Bell was engaged as Professor of Vocal Physiology at the Boston University and his spare time was occupied in conducting experiments with the object of perfecting a "harmonic telegraph," devised on the principle of sympathetic vibration, by means of which he hoped to be able eventually to send simultaneously several telegraphic messages over a single wire without mutual interference.

His apparatus was made to his directions in the electrical workshop of Mr. Charles Williams, of 109 Court Street, Boston, then one of the largest and best equipped electrical shops in the United States. Mr. Charles Williams was well known as a manufacturer of telegraphic and other electrical apparatus and his aid was frequently solicited by numerous would-be inventors of varied genius and pecuniary resources. Amongst these was Graham Bell, who sought Williams' assistance in the construction and trial of his harmonic instruments. One of Williams' assistants at this time was Thomas Augustus Watson, who, in his teens was brought into contact with Graham Bell and in 1875 was deputed to assist him with his experiments and construct for him the experimental apparatus he required.

Graham Bell was directly led to the invention of the telephone through an incident which occurred in connection with the adjustment of his harmonic telegraph apparatus. The essentials of this device were an electro-magnet and a piece of steel spring; one end of the spring was firmly clamped to one pole of the electro-magnet and the other was free to vibrate over the other pole of the magnet. The transmitting device was provided with a contact breaker, which, when in action, maintained the spring in a state of vibration and by adjustment the distant receiver was tuned to vibrate in unison.

There were six transmitters differently tuned and six relative receivers with their springs tuned respectively to correspond.

In an address which he delivered before the Third Annual Convention of the Telephone Pioneers of America, at Chicago, on October 17th, 1913, entitled "The Birth and Babyhood of the Telephone," Mr. Thomas A. Watson thus described the circumstances which led to the production of the first speaking telephone :—

"Coming back to earth, I'll try and tell you what happened that day. In the experiments on the harmonic telegraph, Bell had found that the reason why the messages got mixed up was inaccuracy in the adjustment of the pitches of the receiver springs to those of the transmitter. Bell always had to do this tuning himself, as my sense of pitch and knowledge of music were quite lacking—a faculty (or lackulty) which you will hear later became quite useful. Mr. Bell was in the habit of observing the pitch of a spring by pressing it against his ear while the corresponding transmitter in a distant room was sending its intermittent current through the magnet of that receiver. He would then manipulate the tuning screw until that spring was tuned to accord with the pitch of the whine coming from the transmitter. All this experimenting was carried on in the upper story of the Williams building where he had a wire connecting two rooms perhaps sixty feet apart looking out on Court Street.

"On the afternoon of June 2, 1875, we were hard at work on the same old job, testing some modification of the instruments. Things were badly out of tune that afternoon in that hot garret, not only the instruments, but, I fancy, my enthusiasm and my temper, though Bell was as energetic as ever. I had charge of the transmitters as usual, setting them squealing one after the other, while Bell was retuning the receiver springs one by one, pressing them against his ear as I have described. One of the transmitter springs I was attending to stopped vibrating and I

plucked it to start it again. It didn't start and I kept on plucking it, when suddenly I heard a shout from Bell in the next room, and then out he came with a rush, demanding, 'What did you do then? Don't change anything. Let me see!' I showed him. It was very simple. The make-and-break points of the transmitter spring I was trying to start had become welded together, so that when I snapped the spring the circuit had remained unbroken while that strip of magnetised steel by its vibration over the pole of its magnet was generating that marvellous conception of Bell's—a current of electricity that varied in intensity precisely as the air was varying in density within hearing distance of that spring. That undulatory current had passed through the connecting wire to the distant receiver which, fortunately, was a mechanism that could transform that current back into an extremely faint echo of the sound of the vibrating spring that had generated it, but what was still more fortunate, the right man had that mechanism at his ear during that fleeting moment, and instantly recognised the transcendent importance of that faint sound thus electrically transmitted. The shout I heard and his excited rush into my room were the result of that recognition. The speaking telephone was born at that moment. Bell knew perfectly well that the mechanism that could transmit all the complex vibrations of one sound could do the same for any sound, even that of speech. That experiment showed him that the complex apparatus he had thought would be needed to accomplish that long-dreamed-of result was not at all necessary, for here was an extremely simple mechanism, operating in a perfectly obvious way, that could do it perfectly. All the experimenting that followed that discovery, up to the time the telephone was put into practical use, was largely a matter of working out the details."

As the result of Graham Bell's discovery, which amounted virtually to the fact that his harmonic telegraph device might be utilised to transmit speech, the first speaking telephone proper was constructed hurriedly by T. A. Watson to Graham Bell's instructions. It consisted of one of the harmonic receivers, suitably mounted, with the free end of its spring attached to the centre of a diaphragm of goldbeaters' skin stretched over a circular frame, and is illustrated in Fig. 1.

Although it cannot be said that speech could be carried on successfully by means of this crudely fashioned instrument, its performance was sufficient to establish beyond doubt the feasibility of speech transmission by this principle, and the task of improving and developing it was immediately entered upon by

Graham Bell. He worked assiduously at the problem, assisted by Mr. Watson, and by the middle of 1876 communication could be carried on with much greater ease.

Mr. Watson relinquished his appointment with Mr. Williams in order to devote the whole of his attention to the telephone, being offered an interest in Bell's patents by the latter's prospective father-in-law, Mr. Gardiner G. Hubbard, who was also his financier.

Thereafter progress was rapid, telephones of all sizes and descriptions were devised, constructed and experimented with, until there eventually emerged practically the same telephone which is used as a receiver to-day.

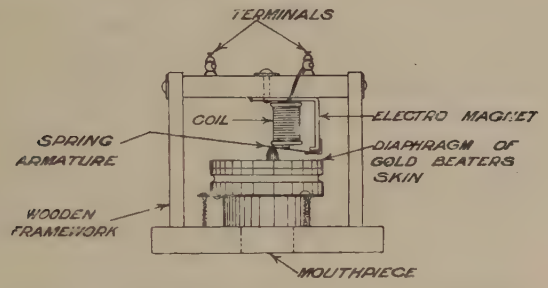


FIG. 1.—Alexander Graham Bell's first telephone.

The name of Williams is intimately associated with the early days of the telephone; not only were the first telephones manufactured in America made by Mr. Williams, but many early switchboards employed by the Bell administration and others in this country were also made by Williams and are mentioned appropriately later on.

During the period in which Graham Bell was at work upon his investigations, Elisha Gray, of Chicago, was also experimenting in a similar direction, and he produced a telephone device almost simultaneously with Graham Bell.

Elisha Gray's telephone comprised for transmitter or sender a diaphragm to the centre of which was attached one end of a metallic rod, projecting downwards into a vessel of insulating material, containing a liquid of comparatively poor electrical conductivity, and provided at the bottom with a metallic contact. An electrical circuit being completed through the liquid and the metallic rod and contact, its resistance would be varied by

vibration of the diaphragm and the resultant electric current varied accordingly. The receiver consisted of a diaphragm with a piece of soft iron attached to its centre opposite to which was an electro-magnet with its coils connected in the line circuit.

On February 14th, 1876, the American Patent Office received two applications for telephone patents, the first one that of Alexander Graham Bell and the second, but an hour or two later, from Elisha Gray. Gray allowed his apparatus to remain undeveloped, whereas Bell proceeded to improve and develop his invention. Priority of invention between Bell and Gray was subsequently contested in the law courts, and ended in a compromise, both patents being ultimately acquired by one company.

In process of development and attempt at perfection, Graham Bell's invention passed through successive stages, several types of instrument being produced, which for the purpose of this volume it is not necessary to detail. His final product was the magneto receiver similar in form to that illustrated in Fig. 154*a* and from this instrument has been derived, with modifications of but comparatively minor importance, the telephone receiver of to-day.

The invention in its early form was exhibited at the Centennial Exhibition held in Philadelphia in June 1876, at which Lord Kelvin (who was then Sir William Thomson) was present as one of the judges. He was greatly impressed with Professor Graham Bell's achievement, and in his Presidential Address before the Mathematical and Physical Section of the British Association for the Advancement of Science, delivered at Glasgow on September 7th, 1876, Sir William made reference to and exhibited Graham Bell's telephone, describing it as "the greatest by far of all the marvels of the electric telegraph."

By the summer of 1877 Graham Bell had considerably improved his invention and in July 1877 Sir William Preece, F.R.S. (then Mr. W. H. Preece), brought to this country the first pair of practical telephones, and in the same year, at the meeting of the British Association in Plymouth, in company with Graham Bell, exhibited the latter gentleman's perfected type of telephone. This instrument was the prototype of the present day telephone receiver, from which it differed in but comparatively minor detail.

In the address entitled "The Birth and Babyhood of the Telephone," previously alluded to, Mr. Thomas A. Watson says :—

"In the following August (*i.e.*, August 1877) Professor Bell married and went to England, taking with him a complete set of up-to-date telephones with which he intended to start the trouble in that country."

Start the trouble Mr. Bell certainly did, some of which trouble it is the author's privilege to describe in the later pages of this volume.

On October 31st, 1877, Graham Bell delivered before the Society of Telegraph Engineers in London a paper wherein he described his invention and gave particulars of some of his researches.

In the course of a lecture delivered before the Society of Arts on November 30th, 1877, Professor Graham Bell related how, on the day previous, he had actually held conversation with a diver who descended into a tank at Messrs. Siebe and Gorman's. The connection was established through the wire coil contained within the breathing pipe as a stiffening device, the earth connection being made to the diver's helmet.

On Monday evening, January 14th, 1878, Professor Bell and Colonel Reynolds were presented to Queen Victoria at Osborne House, Isle of Wight, and, assisted by Mr. C. Wollaston, exhibited the new invention. Telephonic communication was established with Osborne Cottage, the residence of Sir Thomas Biddulph, with whom Her Majesty was able to converse. Songs and recitations were transmitted and later connection was made between Osborne House and Cowes, Southampton and London. At Southampton, Mr. W. H. Preece was in attendance and held conversation with Professor Bell. The notes of a bugle sounding the retreat in Southampton were faithfully transmitted and the tones of an organ played in London were heard with equal success. In a few days' time, Graham Bell received a request from Sir Thomas Biddulph, acting on behalf of the Queen, to purchase the two instruments and wires which had been used, but Graham Bell explained that the two instruments at Osborne were merely commercial instruments and offered a set of telephones made expressly for Her Majesty's use.

On January 22nd, 1878, an attempt was made to transmit

by telephone a portion of a debate in the House of Commons and of the Parliamentary Summary, by means of an ordinary telegraph wire from the gallery of the House of Commons to the office of the *Daily News* in Bouverie Street, Fleet Street. The effort was attended with success and on the following day the information thus transmitted was published in the *Daily News*.

Lieut.-Col. Sir Albert Kaye Rollit, D.L., J.P., was presented by Graham Bell with the second pair of telephones brought to this country.

Graham Bell secured patent rights in this country on December 9th, 1876. (See British Patent Specification No. 4765.)

The first commercial form of telephone instrument, which was known as "Bell's Box Telephone," is depicted in Fig. 2. This instrument was produced in 1877 and was used by Graham Bell for purposes of demonstration during the numerous lectures delivered by him in the United States, in which he was assisted by Mr. Watson. It was used both as transmitter and receiver and in some cases was fitted with a flexible tube to facilitate its use.

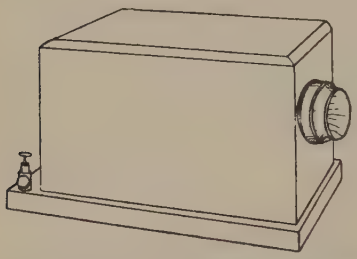


Fig. 2.—Bell's Box Telephone; the first form of commercial instrument.

Inside the wooden case or box was fixed a long horseshoe magnet of steel, its pole pieces being fitted with bobbins of wire connected to the terminals shown in the illustration, in front of which a large iron diaphragm was supported. There was no calling device associated with the first form of this instrument, attention being attracted by striking the diaphragm with any convenient article which was available, but Thos. A. Watson devised a hammer so arranged within the box as to strike against the diaphragm when operated by means of a press button projecting from the front of the case. Some instruments of this type were employed for private lines in London.

As might be expected, the first published accounts of the invention of the telephone excited a great deal of interest in this as well as in other countries, and numerous physicists and others, not excluding the ever present and most enthusiastic amateur, immediately commenced to experiment in their own way.

The well-known string telephone, a reminiscence of the earliest days of the present generation, when this contrivance was purchasable as a toy, was in vogue some 10 years prior to the date of the invention of Bell's device. The interest in the telephone which followed Bell's invention revived curiosity in the string telephone and numerous experimenters occupied themselves in further investigations with this toy. At one period it is understood that a company was formed for the exploitation of a " tight wire " telephone and as mentioned in Chapter VI some circuits were actually worked commercially, but the success achieved was very quickly eclipsed by the commercial introduction of Bell's telephone.

An article in the May and July numbers of the *Telegraph and Telephone Journal* for 1916, entitled, " Telephone Records," gives some interesting information regarding the early consideration given to the telephone by the British Post Office, and the following particulars have been gathered from the pages of that journal.

At the request of the Secretary of the Post Office the Engineer-in-Chief, Mr. R. S. Culley, reported on March 3rd, 1877, as to the capabilities and practical utility of the telephone, which the Secretary described as an instrument " capable of sending several messages simultaneously and giving higher results than are obtainable from any other instrument."

Mr. Culley reported that he had not seen the invention nor was he aware that there was an apparatus in this country. He described the principle as being that embodied in Bell's early and well-known experiment with tuning forks, and stated that in rough hands the system was hardly likely to give greater results than any other instrument.

On September 29th, 1877, Colonel Reynolds, who was Professor Graham Bell's representative in London, offered to exhibit the telephone to the British Government with a view to its adoption by the Post Office, but the Engineer-in-Chief reported against the proposal, observing that his Department was in possession of full knowledge of the details of the invention and that the possible use of the telephone was very limited.

In the same year, Messrs. Fischer and Preece visited America and upon their return submitted a report in which the telephone was commented upon more favourably. They referred to the great progress made in America with Bell's telephone, and gave

it as their opinion that while inductive interference was likely seriously to retard its employment, scientific inquiry and patient skill would probably eliminate all defects. It was considered that the present form of the apparatus was not such as to be of practical value to the Department, but the suggestion was made that encouragement be given to its examination and trial, with the qualification that it was not recommended that any steps be taken to secure its use.

In December 1877 Colonel Reynolds offered to supply the Department with telephones at rates less by 40% than those offered to the public. These terms were set out in a Circular issued at that time and were as follows :—

	Purchase			Rental per annum		
	£	s.	d.	£	s.	d.
For a set of instruments for short circuits .	25	0	0	5	0	0
,, ,, ,, long ,, .	35	0	0	10	0	0

Each set of instruments consisted of a pair of telephones and a call bell. The rental charge was to include the cost of maintenance of the hired instruments, and the costs in both cases covered all royalty charges.

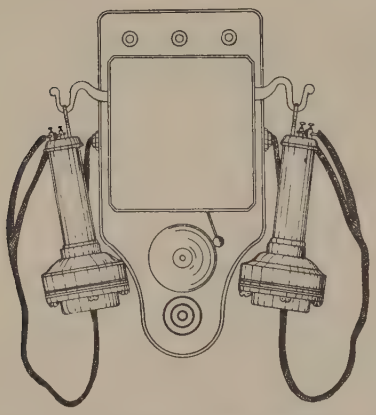


Fig. 3.—Telephone Instrument first employed by The Telephone Company (Bell's Patents), Ltd., 1878.

An illustration of the instrument appears in Fig. 3.

A copy of the circular referred to has recently come into the hands of the author through the good offices of Mr. W. D. Owen of Newcastle-on-Tyne, and as it possesses considerable historic interest it is reproduced in its entirety in Appendix F. Although the circular is not dated, evidence of the period in which it was in circulation is given by a communication which appears on the back. This communication is dated November 29th, 1877; it was written from 12 Queen Street, Cheapside, E.C., being addressed to Mr. J. Groves, 3 Westmorland Terrace, Newcastle-on-Tyne, and was signed W. H. Reynolds.

In the Museum of the Institution of Electrical Engineers,

Victoria Embankment, London, the following exhibits which possess special interest in association with the present chapter are on view :—

(1) " Full sized reproduction of the original Telephone invented in 1875 by Alexander Graham Bell, Presented by J. E. Kingsbury, Esq., May 7th, 1913."

(2) " Early Bell Telephone 1878. This telephone was made on H.M.S. ' Thunderer ' and was installed at Marlborough House for H.M. Queen Alexandra (then Princess of Wales) in 1878 and established a connection between Her Majesty's sitting-room and the school-room. This form of magnetic telephone, patented by Professor Alexander Graham Bell in 1876, was one of the earliest to be brought into practical use. Presented by H.M. Queen Alexandra, August 9th, 1915."

In Appendix E will be found particulars of telephone apparatus of historic interest preserved at the Science Museum, South Kensington, and by the Institution of Electrical Engineers, Victoria Embankment. London.

CHAPTER II

THE PARENT TELEPHONE COMPANIES AND ESTABLISHMENT OF TELEPHONE EXCHANGE SYSTEMS, 1878–1880

THE first telephone company to be floated in this country was registered on June 14th, 1878, under the title "The Telephone Co., Ltd. (Bell's Patents)." It was formed for the purpose of working Graham Bell's patent with a capital of £100,000. Mr. James Brand was first chairman of the company and Mr. Fred Ormiston was appointed manager, with offices at 36 Coleman Street, London, E.C., which address thus became the first authentic home of Graham Bell's telephone in London.

The first commercial telephone instruments consisted of a bell to indicate receipt of a call, a press button and battery, a switch-hook and two Bell telephones, one used as receiver and the other as transmitter. The instruments were originally imported from The Bell Telephone Co. of America. With the receiver upon the switch-hook the bell was directly connected to the single line, and the transmitter and receiver were disconnected therefrom. On removal of the receiver from the switchhook, the bell was disconnected and the receiver and magneto transmitter were put in circuit with the line for speaking purposes.

A telephone instrument of this type is illustrated in Fig. 3.

At the commencement The Telephone Co., Ltd., confined its operations to the sale of telephone instruments and appurtenances and to fitting private lines in various parts of the country, and agents were appointed in many of the important towns in the provinces.

One of the first private telephone lines to be erected in the vicinity of London was from the residence of Mr. H. F. Tiarks, at Chislehurst, to his stables. The receiver was of the old box form and was fitted with a long, flexible tube.

The first private telephone lines between North and South London crossed the River Thames from the Lion Brewery to Hayes Wharf and were as below :—

(*a*) Hayes Wharf to Hayes Wharf Office.

(*b*) Williams, Brown and Elmsley, Billiter Square, to Davis Wharf, Shad Thames.

(*c*) Petty, Wood and Co., King William Street, to Southwark Bridge Road.

(*d*) De Claremont, Donner and Lee.

An advertisement issued by The Telephone Co., Ltd., in May 1879 in the form of a pamphlet of twenty pages described and gave instructions for using the telephone. Examples of the application of the telephone for practical purposes were given in the form of sixteen pictures, a pair of which is reproduced in Fig. 4.

The following notice appeared in the forefront of the pamphlet :—

TELEPHONES.

CAUTION.

It having been brought to the notice of the Directors of The Telephone Company, Ltd., that many persons are infringing the Company's Patent granted to William Morgan Brown as Agent for and on behalf of Professor Graham Bell, the public are hereby warned not to make, sell, or use any Telephones or Telephonic Apparatus or any parts thereof, except such as have been supplied by the Company, who are the sole Proprietors of Professor Bell's Patent, and Notice is hereby given that proceedings will be at once taken against all persons acting in contravention of this notice.

Dated this 30th day of April, 1879.

By Order,

W. H. MORRIS, *Secretary*

THE TELEPHONE COMPANY, LIMITED,
36 *Coleman Street, London, E.C.*

This announcement was an early indication of the possibilities for infringement which the telephone offered and of the fact that the occurrence of such infringements was considered not improbable.

Prices quoted in the pamphlet under date May 24th, 1879, were as below :—

	Each. £ s. d.		Per annum each. s. d.
Telephone, Ebonite, hand pattern . .	1 1 0	Royalty	10 6
,, Snuff Box, ,, ,, . .	15 0	,,	10 6
,, Wood Box, ,, ,, . .	1 10 0	,,	10 6

(The Royalty may be commuted at any time by a payment of Five Years in advance.)

Telephone, Call Bell with Push and Automatic Switch . .	£3 0 0
Indicators complete, with Bell, Push, Automatic Switch and Commutator for Telephone lines, for use where a number of wires are led into the same office, so that one pair of telephones is sufficient for communicating on any number of lines	Varying with number of lines.
Leclanche Battery in Wood Case for use with above .	from £1 0 0

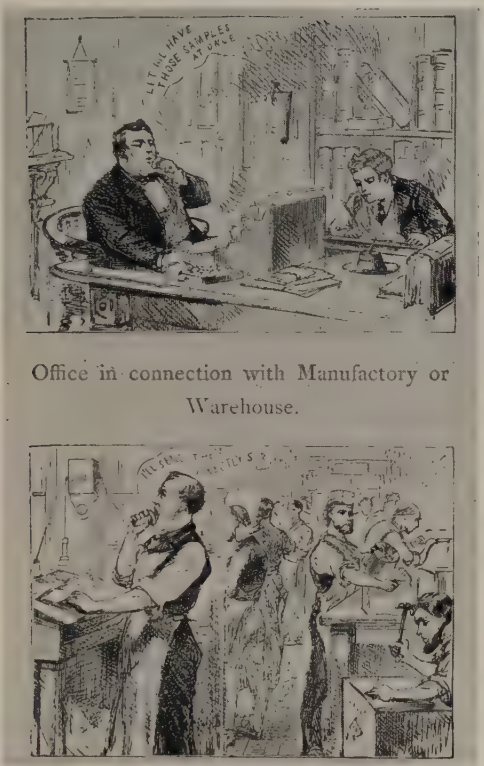
The company advertised that they would, if required, fit up the lines or would supply the telephones to be fitted by any competent telegraph engineer or electric bell fitter.

Included in the pamphlet was a list of some of the establishments using the telephone, in which Her Majesty's household and important institutions and companies were included, numbering in all nearly forty.

On October 20th, 1879, the general manager of The Telephone Co., Ltd., Mr. J. B. Saunders, issued a price list for telephonic apparatus in which it was stated that a considerable reduction in prices had been effected with a view to induce the public to adopt the telephone on a more extensive scale than hitherto. It was stated that the instruments were sold only upon an undertaking being given that they would not be used in connection with a telephonic exchange.

The prices quoted were as follows :—

	£ s. d.
Switch bell, ringing button, transmitter with one Telephone and Batteries complete . . . . . each	10 0 0
Ditto with telephone but exclusive of batteries . . .	9 0 0
Ditto exclusive of telephone and batteries	6 7 6
Switch Bell with button and pair of telephones and battery complete . . . . . each	6 0 0
Ditto exclusive of battery	5 5 0
Improved ebonite telephones (including Royalty) . . each	2 17 6
Indicator for two or more lines, at per indicator . . .	—
Leclanche batteries, at per cell	—
Gutta percha wire, at per yard	—
Galvanised Iron ditto	—



Office in connection with Manufactory or Warehouse.

FIG. 4.—Example of the early application of the Telephone for practical purposes, from an advertisement issued by the Telephone Company, Ltd., in May 1879.

(Reproduced from a booklet loaned by the late Mr. J. W. Ullett.)

[To face page 22.

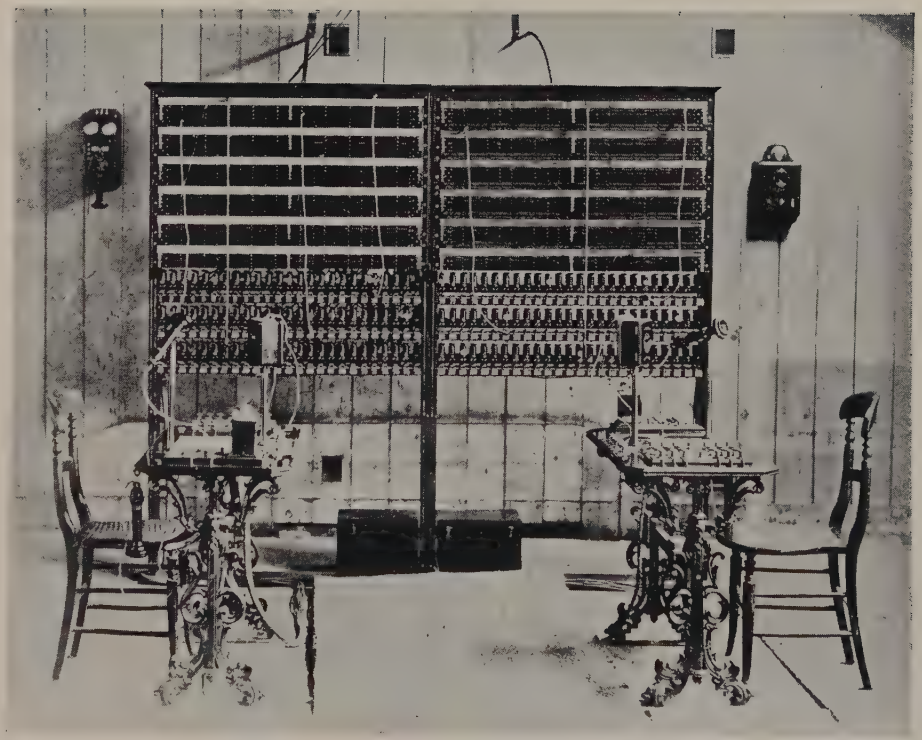


FIG. 5.—The First Telephone Exchange in London, 36 Coleman Street, E.C. The Telephone Company, Ltd. Two-panel Williams switchboard.

(From a photograph loaned by Mr. H. Kitchen.)

[*To face page* 23.

The list concluded with a statement that a quantity of telephones in wood cases and other telephone apparatus was offered for sale at considerably reduced prices, an early indication of the rapid improvements made in telephone apparatus and the obsolescence of the wood case telephone receiver.

Conception of a central switching station, by which one party provided with a telephone circuit might be placed in communication with any other party possessing a similar telephone installation, seems to have had its origin in the switching systems which had previously been introduced in association with telegraphs. In America, telegraph signalling switching systems were already in being when the telephone was invented and for purposes of intercommunication the telephone appears to have been introduced in America to work in conjunction with existing telegraph switching systems in a manner somewhat similar to that in which it was introduced by the British Post Office in this country. (See Chapter V.)

The telephone exchange came into practical existence in America before its introduction into this country. Apart from the application of telephones to the existing telegraph switching systems just mentioned, the first independent commercial telephone exchange was established in America in January 1878. The idea of the telephone exchange may, therefore, be regarded as imported from America into this country.

Following the lead of America, The Telephone Co., Ltd., opened the first telephone exchange in London, in August 1879. It was housed at 36 Coleman Street, E.C., and was established with some seven or eight subscribers.

Fig. 5 is from a photograph of the switchboard of this exchange taken in September 1879. The switching arrangements comprised two separate and distinct parts, viz. (*a*) a connecting position, and (*b*) answering or talking operators' positions, the latter consisting of two tables situated apart from and in front of the connecting position; they may be seen in the forefront of the illustration.

The connecting position consisted of two panels or sections each made up of—

(*a*) Three rows of 25 drop indicators each.

(*b*) Three rows of 25 flat spring jacks or slippers as they were then termed, one situated immediately below and associated

with each indicator. There was thus accommodation for as many as 150 subscribers' lines.

(*c*) Twenty-four pairs of horizontal metal strips provided with a series of holes for reception of circular pegs, extending the full length of the upper portion of the section.

(*d*) A set of flexible cords each provided with a circular brass peg at one end and at the other a flat plug or jack, as it was then termed, consisting of a flat brass plate mounted upon a piece of insulating material.

Each answering or talking operator's position comprised a transmitter and receiver and a series of connecting, earthing, and battery keys.

The circuit connections of the switchboard together with details of the type of indicator employed are shown in Fig. 6.

The pairs of horizontal bars were identified by code letters A,A,—B,B,—C,C, etc., to X,X, and they were also distinctively coloured to facilitate identification. The uppermost pairs of bars on each connecting section were permanently wired to the keys on the respective talking operators' tables, the remainder being spare and available for connection to additional tables if and when required.

The slipper, or jack, as it would now be termed, consisted of a flat brass spring normally making contact with a brass plate which was connected to earth through the respective subscriber's indicator. Each incoming single line was directly connected to the upper contact of the slipper.

By depression of the calling button on the subscriber's instrument a battery current was transmitted over his exchange line to the exchange to the upper spring and lower plate of the slipper, through the wire coils of the calling indicator to earth, thus causing the indicator shutter to be released. The connecting operator then inserted the flat jack at the end of one of the loose cords into the slipper associated with the indicator of the calling subscriber, which had the effect of connecting the cord to the subscriber's line, and disconnecting the subscriber's indicator and earth connection. The circular peg at the other end of the connecting cord was then inserted into one of the holes in a brass strip which was not in use, and the indicator shutter restored.

This operation placed the subscriber's line in connection with the keys controlled by the answering operator, to whom the connecting operator, if necessary, then indicated the code of the bar to which he had connected the calling subscriber. By

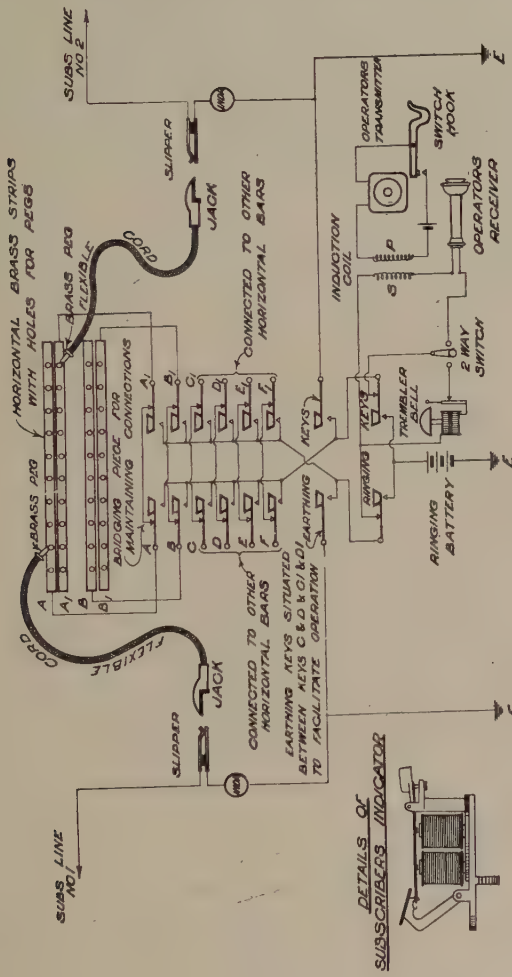


Fig. 6.—Electrical connections of switchboard employed by The Telephone Company, Ltd., at 36 Coleman Street, E.C.

depressing the appropriate keys, the answering operator's instrument was switched to the bar indicated, and the calling subscriber's requirements were ascertained.

The connecting operator was then instructed to connect the wanted subscriber's line to the horizontal bar which formed a

pair with the first one, a second connecting cord being used for the purpose. The required subscriber was then called by means of a key associated with the answering operator's instrument and, when his attention had been secured, he was informed of the pending conversation, and the two subscribers left connected through the two connecting cords, and back contacts of the two keys directly connected to the horizontal strips.

When speaking with a subscriber from the operating table it was necessary for the operator to depress two keys simultaneously, the key directly connected to the horizontal bar and the earthing key, as may be seen by reference to the diagram in Fig. 6.

In order that the two keys might be depressed by the fingers of one hand when speaking, the earthing keys were placed respectively between the keys marked C and D and C_1 and D_1, but in the diagram, for sake of simplicity, they have been placed differently.

The set of seven pairs of keys was situated to the left of the operator to facilitate their manipulation by means of the left hand; on the right was a small board upon which was mounted a two-way switch, the two ringing keys, and a trembler bell. The two-way switch was used to connect the bell with the operator's circuit when not in use. There were actually two receivers fitted, the second one normally being upon the switch-hook to break the primary circuit. The second receiver was supplied to enable a second party to listen in circuit with the operator and was used chiefly for demonstration purposes.

The switchboard which has been described was imported from America and was known as a "Williams" switchboard. It was probably manufactured by Mr. Charles Williams, jun., of Boston.

The subscriber's indicator was connected between the lower plate of the slipper and earth, but was disconnected from the circuit when the answering or connecting jack was inserted; consequently there was no clearing signal, but as each through connection was maintained through a conductor bridging the back contacts of the keys on the operating table, the operator there was enabled to supervise each call, although interruption of conversation between subscribers was liable to occur in so doing.

Amongst the first subscribers to the telephone exchange at 36 Coleman Street were the following :—

Harvey Brand and Co.
W. C. Quilter.
Forbes (L.C. and D. Rly.).
Croll (Wool Exchange).
George Chubb and Son.
Samuel Dobree and Sons.
Marine Insurance Co., Old Broad Street, E.C.
G. and R. Dewhurst.
Ashurst, Morris and Co.
Dent Bros. and Co.
Quilter, Ball and Co.
Smith, Payne and Smith.
Emile Erlanger and Co.

A system of telephonic intercommunication by means of a switchboard was thus satisfactorily established and the telephone exchange in London became an accomplished fact.

The company's enterprise, being so far attended with success, and receipt of applications for telephone service continuing, they set about the extension of their system, and before the end of the year 1879 two further exchanges were opened, one at Leadenhall House, 101 Leadenhall Street, and the other at 3 Palace Chambers, Westminster.

Although the switchboard employed at Leadenhall Street was of the slipper jack type, it was not manufactured in America and it embodied several novel features which were absent in the Williams board at Coleman Street. It was manufactured by the Silvertown India Rubber, Gutta Percha and Telegraph Works Co., Ltd. Instead of the horizontal bars provided in the Williams switchboard, certain brass contacts were employed, and when the switchhook of the subscriber's telephone descended, upon the receiver being replaced thereon after conversation, the clearing signal was automatically transmitted to a galvanometer situated at the exchange. The subscribers' instruments were of Silvertown design and construction.

New subscribers were forthcoming and were quickly connected up and at the end of the year the telephone company's system served about 200 subscribers.

At this time the interest evinced by the Post Office in the science of telephony and the telephone business was indicated by a visit paid to the Coleman Street exchange on November 7th, 1879, by Mr. E. R. Graves, the Engineer-in-Chief, and Mr. W. H. Preece, electrician to the Post Office. They were shown the Bell Co.'s switchboard in operation, and Mr. J. B. Saunders, the manager, explained the switching apparatus and the operating methods. Particulars of this visit, and of a report subsequently prepared by the two gentlemen named, for the information of the Secretary of the Post Office, are given in an article, previously referred to, entitled "Telephone Records," published in the May and July numbers of the *Telegraph and Telephone Journal* for 1916. The report mentioned that there were 52 or 55 subscribers and that Bell telephones and Blake transmitters (which will shortly be referred to) were in use, also that in view of there being little going on, and the circuits being only short, the effects of induction were unobservable. There were 49 wires then crossing over Moorgate Street from the Coleman Street premises. Special reference was made by Mr. Preece, who supplemented Mr. Graves' report, to the one defect of the system, viz., that the Central Station was unable to tell, except by trial, when the subscribers had ceased to communicate with each other. This was due to the fact that the indicators were originally connected between the lower plate of the slipper and earth as shown in Fig. 6 instead of in the line circuit. He also referred to the fact that several plans had been tried to remedy this disadvantage, one, which was under trial at the time of the visit, being dependent upon a current sent by either subscriber, or automatically by the switch, to move a galvanometer which also acted as a relay and rang a bell.

This difficulty was eventually removed, as explained in the following chapter, by connecting the indicator in the line circuit, so that it might be utilised for receipt of a clearing as well as a calling signal, the two indicators being left in circuit during conversation.

The Telephone Co., Ltd., was probably the first telephone company to place an order for the work of erection of overhead wires, for a contract was let by that company to Messrs. Reid Bros., of London, for the erection of ten wires from Coleman Street to Mincing Lane. It is interesting, in these days,

to note that, owing to an obstruction encountered in the form of a chimney, only nine of the wires were completed. At one time, Messrs. Reid Bros. acted as contractors to the Magnetic Telegraph Co.

The telephone companies were always credited with particular ability to protect and further their own interests, and it cannot be denied that they were given every cause to practise alertness in this direction. The Telephone Co., Ltd., and its successor, the United Telephone Co., did their very utmost to protect and uphold their patent rights, and to preclude opposing parties from obtaining the use of instruments which, by virtue of the patent rights they possessed, were under their control, and they were generally successful.

Such an attempt was made by the Telephone Co., Ltd., in an agreement they entered into with Messrs. Scott and Wollaston, which empowered the latter firm to manufacture, and dispose of, telephones, under a stipulation that they were not to be employed for the purposes of exchange service, the telephone company thus attempting to reserve to itself the exclusive ability to practise exchange business. The type of instrument manufactured by Messrs. Scott and Wollaston was known as the " Gower Bell Telephone," a combination of a Gower receiver and a Gower transmitter, both of which instruments are described and illustrated in Chapters V and XVII. Gower ultimately acquired the licence issued to Scott and Wollaston by the Telephone Co., Ltd., and formed the Gower Bell Telephone Co., who thus assumed the interests of the first-mentioned firm. The Gower Bell Company eventually supplied the Post Office with instruments manufactured under the agreement referred to and in due course some of them were utilised in connection with the exchange telephone service of the Post Office. On becoming aware of the position the Telephone Co., Ltd., gave consideration to the legal aspect of the case and were advised that although the parties entering into the agreement were legally bound by the prohibition clause, it could not be held to be binding upon purchasers of the instruments.

The Telephone Co., Ltd., was not destined to remain in undisputed control of the field for very long, the advent into this country of the Edison carbon transmitter bringing with it the first signs of competition.

Edison, the well-known inventor, entered the domain of telephony as an expert in the service of the Western Union Telegraph Co., and on July 20th, 1877, an application was filed in the name of Thomas Alva Edison, at the American Patent Office, for the first type of his carbon transmitter.

On July 30th of the same year, a similar patent was filed in this country. It was not, however, until December 30th, 1878, that the transmitter was introduced to public notice by Professor Barrett in a lecture which he delivered at the London Institution. It was brought over to this country by Mr. James Adams.

The theory underlying the variable resistance carbon transmitter devised and patented by Edison was that the electrical resistance of carbon was diminished by the application of pressure. It will, no doubt, be remembered that a one time well-known form of carbon rheostat was devised by Edison in 1873. In this rheostat, or variable carbon resistance, a number of square or reactangular plates of carbon were packed together into a frame, from which they were insulated, and in which they were free to move. At each end of the pile of carbon plates a terminal was provided; one terminal was in the form of a screw by means of which the pressure might be varied; as the pressure between the plates was increased, so the electrical resistance diminished and *vice versa*. The arrangement was not altogether satisfactory as a variable resistance inasmuch as its resistance was not stable; at comparatively high resistances, *i.e.*, when the pressure exerted by means of the screw was inconsiderable, the slightest vibration had a disturbing effect. In this arrangement lay the secret of Edison's carbon telephone transmitter, but he utilised compressed lamp black enclosed in a chamber with contact discs of platinum on either side. One of the discs of platinum was fixed; upon the other was mounted an ivory button abutting against a mica diaphragm which received the sound vibrations to be transmitted. The transmitter eventually was made up in the form illustrated in Fig. 7.

Immediately upon its arrival in this country the Edison transmitter was brought into experimental use. On November 11th, 1878, in order to test the efficiency of the instrument, a trial was made over the telegraph line belonging to Messrs. J. and J. Colman between Norwich and the firm's offices in Cannon Street,

London. This was one of the first occasions on which long distance transmission was attempted in this country. The line existed along the Great Eastern Railway and was 115 miles long. Mr. Adams, the inventor's professional representative, was present at the Norwich end.

About this time an American, named Bayley, endeavoured to introduce in London a carbon transmitter which, he contended, was clear of the Edison patent, but apparently his exertions did not fructify.

The Bell Co. were very closely watching events and, becoming acquainted with the fact that a magneto receiver had been used in conjunction with the Edison transmitter in London, they

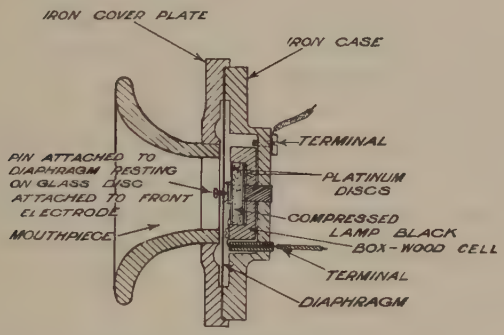


FIG. 7.—The "Edison" transmitter, as used in the Edison telephone instrument.

threatened Edison's representative with litigation in order to prevent infringement of their patent rights. Although the Edison transmitter was satisfactorily protected in England, it was, of course, of no utility without a receiving instrument, and Edison was immediately acquainted with the position of affairs by his London agents.

Edison, with remarkable imperturbability, expressed his intention of remedying the unsatisfactory position by the production of a new receiver on an entirely new principle, and immediately set about the invention of an instrument designed on lines altogether dissimilar to the magnetic receiver of Bell, and which would operate satisfactorily with the transmitter he had already patented.

The result was the production of a most remarkable instrument

variously known as the "motograph receiver," "electro-motograph," "loud speaking receiver," but perhaps more commonly as the "chalk receiver." It was received in this country in March 1879, being brought over by Mr. Chas. P. Edison, the inventor's nephew.

Mr. Edison announced that the first instruments received had been "thrown together" in the short space of five days and that they were only experimental. At the time of their production Edison was very actively employed with experiments and inventions relating to electric lighting.

On Tuesday, April 29th, 1879, the Edison loud speaking telephone was exhibited at the rooms of the Royal Society. Mr. Spottiswoode, President of the Royal Society, and several other gentlemen of eminence, including Sir John Lubbock, were present. One end of the demonstration line was in the laboratory of the Institution, and a passage from a speech delivered by Mr. Gladstone on the previous evening was clearly heard at Burlington House upon being read at Albemarle Street.

In May 1879 the instrument was exhibited at the Royal Institution and also at the Society of Arts.

In the production of this receiver, Edison reverted to a discovery which he had made in 1873, when experimenting with a chemically treated paper in association with an electric current for the purpose of effecting an improvement in telegraphy. It was not until 1876, however, that his discovery was adapted to the reproduction of sound, principally musical tones, and not until 1878 was it directly applied in the construction of a loud-speaking telephone receiver in the circumstances which have been related.

The principle involved in Edison's discovery was that the friction between a contact point and a moving strip of paper moistened with a certain chemical solution was varied by the passage of an electric current between the moistened paper and the contact point. The action was roughly proportional to the strength of the current. In the remarkable telephonic receiving instrument devised by Edison, this principle was applied in the form of a rotating cylinder of chalk, moistened with potassium iodide, associated with a diaphragm of mica, to the centre of which was rigidly attached a brass spring carrying at its other extremity a platinum contact piece which engaged with the

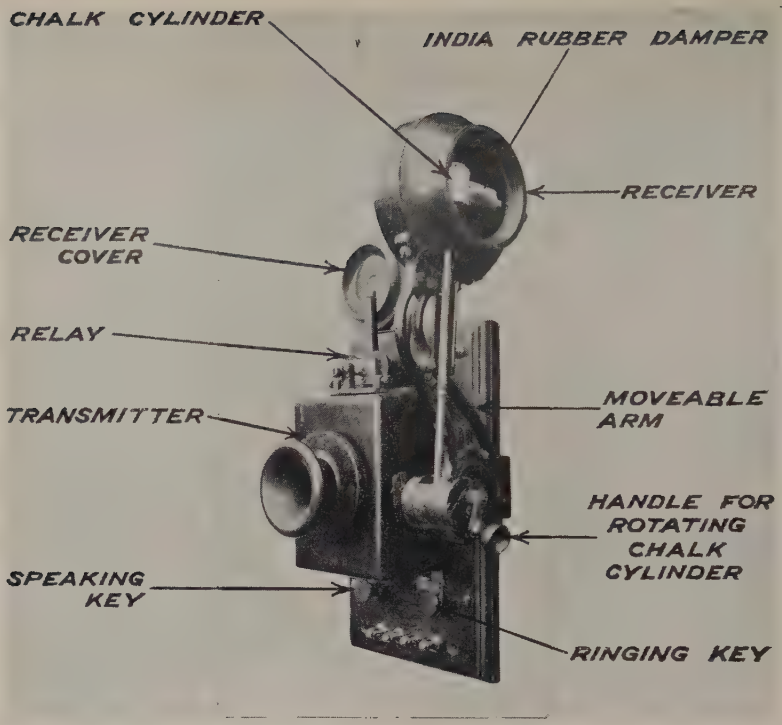


FIG. 8.—Subscriber's Telephone Instrument employed by The Edison Telephone Company of London, Ltd.

(From a photograph of an instrument lent by Mr. R. W. Jackson.)

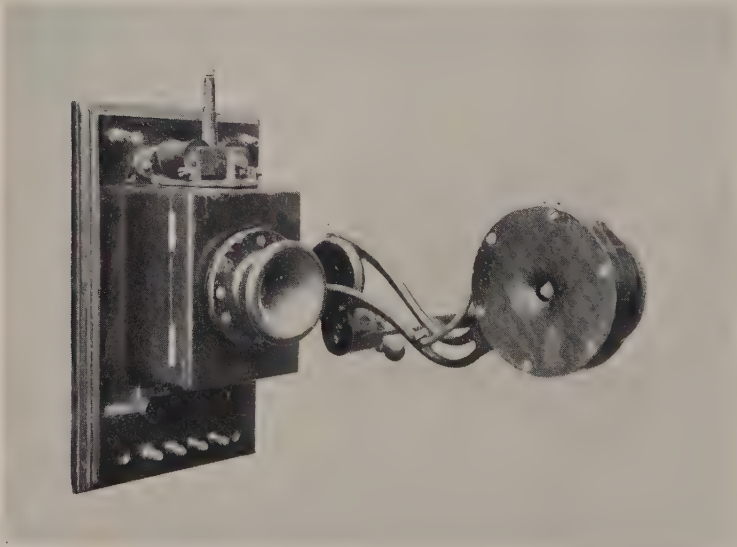


FIG. 9.—Subscriber's Telephone Instrument employed by The Edison Telephone Company of London, Ltd., showing receiver lowered to position for reception.

(From a photograph of an instrument lent by Mr. R. W. Jackson.)

[*To face page* **33.**

cylindrical surface of the chalk. The chalk cylinder was rotated by hand through a worm gearing. Variations in the "drag" of the platinum contact piece upon the chalk cylinder caused by electrolytic action set up by the varying, minute telephone currents, were communicated to the diaphragm, and in this way sounds were emitted to correspond with those made in front of the transmitter.

No. 6 Lombard Street became the headquarters of Edison's London representatives, and an experimental exchange was installed there with about six subscribers' lines.

The introduction of the Edison receiver placed the representatives of Edison in a position to compete with the Bell Company, and Colonel George E. Gouraud, who represented and held power of attorney for Edison in London, was successful in forming the Edison Telephone Co. of London, Ltd. The company was floated on August 2nd, 1879, with a capital of £200,000, the Right Honourable E. P. Bouverie becoming chairman.

A tariff of £12 was decided upon in order to compete satisfactorily with the Bell Co.'s existing tariff of £20, an exchange was established at 11 Queen Victoria Street and opened for service to subscribers in September of the same year, in place of the exchange at 6 Lombard Street. The subscribers' instruments were a combination of the Edison carbon transmitter and the Edison chalk receiver.

Illustrations from photographs taken by the author of the subscribers' instrument employed by the Edison Co. appear in Figs. 8 and 9. This remarkable instrument comprised an Edison carbon transmitter, Edison chalk receiver, induction coil, two keys and a call bell or a relay for closing a local bell circuit for calling purposes. The transmitter was fixed to the front of a case containing the induction coil, and on the top was mounted the bell or relay. The receiver was carried on the end of a movable arm, or bracket, to permit of it being brought down into a position opposite the right ear when speaking, an arrangement found to be unnecessary in practice, owing to the loud speaking properties of the instrument. In Fig. 9 the supporting arm carrying the receiver is shown in the lowered position in readiness for reception, and in Fig. 8 the cover of the receiver mechanism has been removed, in order to disclose the chalk

cylinder within. The handle was for rotating the chalk cylinder during reception. Two keys will be observed at the bottom of the baseboard; the right hand one was a battery key for calling purposes, and the left hand one for closing the local transmitter circuit when speaking. This instrument, complete with transmitter, receiver, induction coil, and the necessary signalling

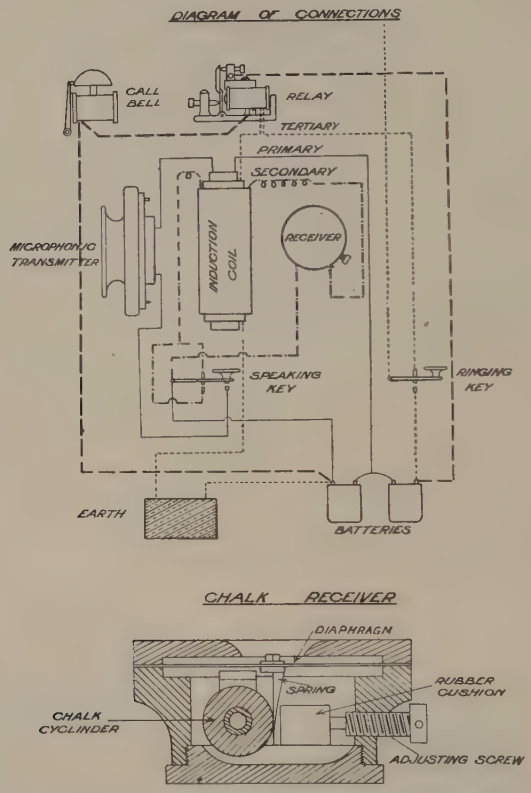


Fig. 10.—Electrical connections of Edison telephone instrument and section of Edison chalk receiver.

apparatus was described in British Patent Specification No. 5335 of December 31st, 1879, and a diagram of the electrical connections derived from the specification is given in Fig. 10.

It will be observed that the induction coil had three windings, the primary being in circuit with the transmitter, one cell of the battery and a key (left hand), the secondary in series with the relay, line, and earth through a second key (right hand),

and the tertiary in series with the chalk receiver, and the back contact of the first-mentioned or left hand key. The connections may be readily traced from the diagram. In order to retain in circuit the transmitter, whilst speaking, it was necessary to keep the left hand key depressed.

The patent specification referred to made reference to two previous specifications of Edison, viz. Nos. 2909 of A.D. 1877 and 2396 of A.D. 1878.

By the end of the year 1879 the Edison Co. had opened up two further exchanges, one in Eastcheap and the other in Chancery Lane, and in 1880 there were upwards of 170 subscribers connected to that company's system.

The switchboard used by the Edison Telephone Co. was entirely different in principle from that used by the Bell Co., being an adaptation of the Umschalter switch. This device was at one time used by the Post Office as a means for connecting as required A B C telegraph instruments, rented by various firms and individuals from the Post Office, and receives further mention in Chapter V.

An idea of the arrangement of a simple form of Edison switchboard may be gathered from Fig. 11. Each board was designed to accommodate 24 subscribers' lines. At the top of the board was a row of 24 heavy brass terminals. To each terminal an incoming subscriber's line was connected. Two rows of 12 drop indicators each were arranged below these terminals. Below the 24 indicators was a second row of terminals, and below these again the switching device proper, which consisted of :—

(1) A series of vertically arranged strips or bars of brass, one for each subscriber's line.

(2) A series of similar strips arranged horizontally, and behind the vertical bars, from which they were insulated.

The crossing strips were half-lapped so as to present a level face, but in such a manner that they were effectively insulated one from another. Holes were provided between the crossing strips, so arranged that on the insertion of a circular metallic peg the corresponding vertical and horizontal bars were electrically connected. In order to place two subscribers in communication, two pegs were inserted, so as to place the two vertical strips to which the respective subscribers' lines were joined in contact with the same horizontal strip.

Each terminal of the upper row of terminals was wired, through a drop indicator, to the corresponding terminal of the lower row, and thence to one of the vertical bars of the switchboard. One of the horizontal bars was earth-connected, this

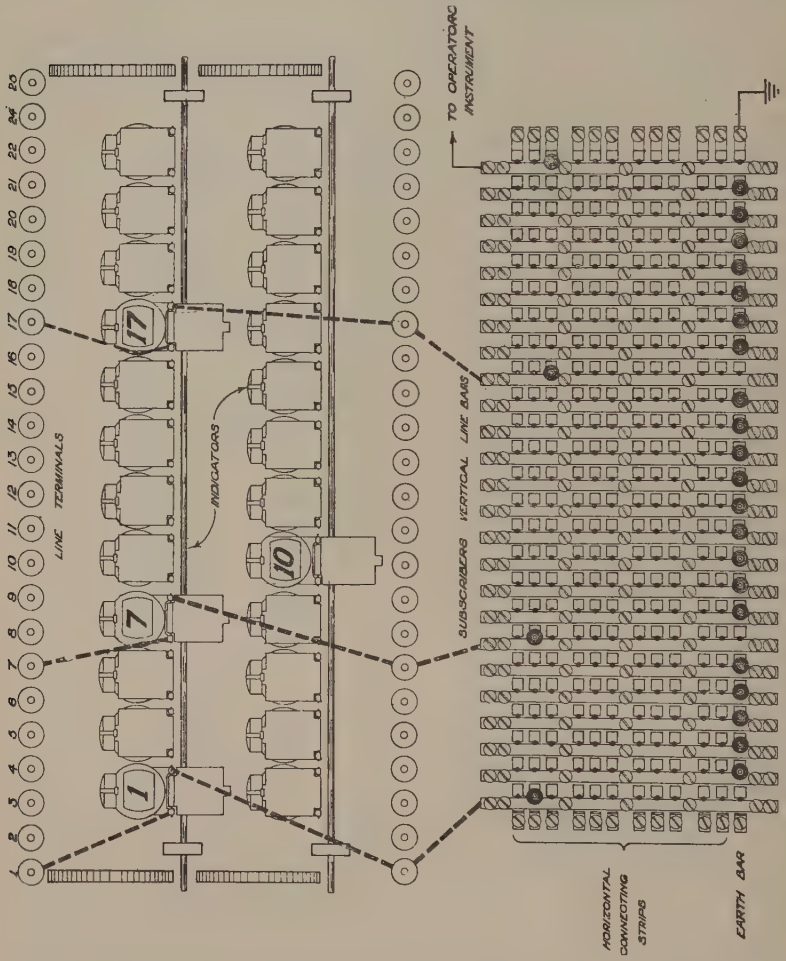


Fig. 11.—Electrical connections of Edison switchboard for 24 lines.

being the bottom one in the case illustrated in the diagram, and normally, pegs were inserted so as to connect all the subscribers to this bar. The operator's telephone was connected to the end vertical bar. The horizontal bars were for connecting purposes only. On the intimation of reception of a call by the falling of one of the indicator shutters, which displayed the

calling subscriber's number, the operator connected his instrument to the calling line, first, by removing the peg which connected the calling subscriber's line with the earthed bar to another hole in the same vertical strip opposite one of the spare horizontal bars; secondly, by moving the peg connecting the operating instrument with the earthed bar to the hole in the same vertical bar corresponding horizontally with the hole in which previously he had placed the subscriber's peg. On ascertaining the number of the subscriber required, he utilised another spare horizontal bar in a similar manner, calling the required subscriber and informing him of the pending connection. The two subscribers were then placed in direct communication by transferring the peg in the called subscriber's vertical strip used by the operator for calling him, to the hole in the same vertical strip corresponding horizontally with the position of the peg in the calling subscriber's vertical strip. The peg in the vertical strip connected to the operating instrument was then transferred to its normal position and the two indicators were restored. Cessation of the conversation was indicated by one or other of the subscribers depressing their calling keys, which caused both indicator shutters to fall; the pegs in use for the connection were then transferred to their normal position.

When the number of subscribers to be accommodated exceeded 24, two or more boards were utilised, certain of the horizontal strips on the individual boards being wired together so as to form, as it were, transfer circuits by means of which subscribers connected to different sections might be connected.

A Provisional Specification for the Edison switchboard was lodged at the Patent Office by Arnold White, of Queen Victoria Street, London, on behalf of Thomas Alva Edison, of Menlo Park, in the State of New Jersey, U.S.A., on September 20th, 1879. The patent was described as " Improvements in Apparatus employed in connection with Telephones for the Purpose of Notifying and of Facilitating and Obtaining Interchangeable Communication between Telephonic Circuits," and was assigned the number 3794.

There are minor differences between the Edison switchboard which has been described and that illustrated and described in the specification, and it is evident that the switchboards of this type brought into use at different exchanges were not all

arranged on identical lines. It will have been observed that, in the switchboard illustrated in Fig. 11, the operator's telephone was connected to an extra vertical bar provided for the purpose, there being 25 vertical bars, whereas the number of subscribers accommodated was but 24. In the switchboard illustrated in the patent specification, there are but 24 vertical bars, the operator's telephone being permanently connected to the seventh horizontal bar only. This provision reduced the number of operations to be performed by the operator in answering a subscriber to the simple transfer of the metallic peg associated with the calling subscriber's circuit from its normal position to the hole situated at the point of crossing of the same vertical bar and the seventh horizontal bar.

The operator's work was further simplified by provision made for the subscriber originating the call, to himself ring the called subscriber, as soon as the operator had placed the two circuits in electrical connection, an arrangement which probably was found not to work satisfactorily in actual practice.

It is not unlikely that, in the later types of Edison board, both a vertical and a horizontal strip were connected to the operator's telephone in order to facilitate operating.

Considerable impetus was imparted to the progress of the telephone as a talking machine by the invention, by Professor Hughes, in May 1878, of the microphone, and from it were derived all the later forms of practical carbon transmitters, of which many quickly followed. David Hughes was born in London, but for the greater part of his life had lived in the United States. He it was who evolved, while resident in America, the well-known type-printing telegraph of his name. Hughes' investigations were made known and his experiments described to the Royal Society on May 8th, 1878, and on May 25th, 1878, the successful working of the microphone was demonstrated at a meeting of the Society of Telegraph Engineers in London. Professor Hughes did not, however, patent his microphone. Had this been the case, the history of the telephone might have been subjected to further patent complications, which, happily, by this omission on the part of Professor Hughes, were avoided. The number of carbon transmitters which followed Hughes' microphone was legion and they were all based on the same principle.

The next advance was the invention and introduction of a transmitter, which went far to revolutionise the science of telephony, and did much to popularise the telephone as a commercial and social asset. A patent, numbered 229, was, on January 20th, 1879, granted to W. R. Lake as importer for "Improvements in Telephones." By an indenture dated January 8th, 1880, this patent was assigned to Francis Blake, the inventor, and the invention became known as the "Blake Transmitter." This instrument was greatly superior to the transmitters which had preceded it. In articulation, it was excellent. Its greatest drawback eventually proved to be that it was unsuitable for long-distance transmission, and an increase

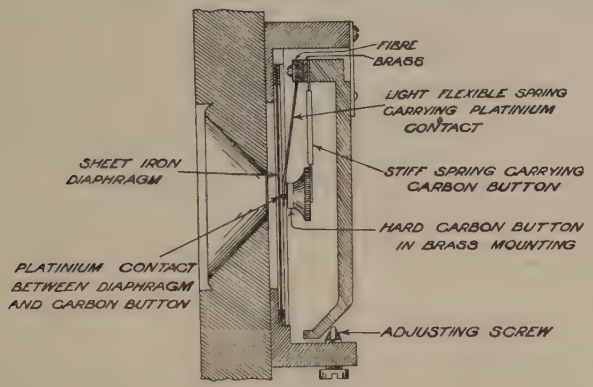


FIG. 12.—The Blake transmitter.

of battery power had no beneficial effect in this direction. This disadvantage was, however, not apparent at the time referred to, as long-distance transmission in this country was non-existent. The transmitter was, therefore, particularly suited for the requirements of the period, and it continued to give admirable service for many years, in fact, until it was displaced by the improved "Hunnings Transmitter."

A section of the Blake Transmitter is given in Fig. 12.

The relative position of the two competitive telephone companies was at this time rather peculiar. The Telephone Co., Ltd., possessed the rights over a most efficient instrument when used as a receiver, but as a transmitter, in which capacity it was also used by that company, it was far from efficient. The Edison Telephone Co. of London, Ltd., on the other hand, had

a transmitter which was greatly superior to the instrument in use by the Bell Company, and a receiver which was far from satisfactory in actual practice. The Bell Company were, at this critical time, enterprising enough to acquire the right to use the Blake transmitter, and they immediately applied it to their system, discarding as transmitter the magneto telephone of Bell. A new instrument, illustrated in Fig. 13, was designed, with the Blake transmitter in place of the magneto transmitter. The new instruments were known as " Silvertown Sets " and a commencement was made to replace the old instruments with the new ones. This change placed the Bell Company in a much superior position to the Edison Company and the consequence was that the latter company brought an action for infringement against the Telephone Co., Ltd. The case was, however, never brought to an issue. Probably influenced by the difficulties and dangers arising out of competition, and also by the possible trend of the legal proceedings, the two companies amalgamated their interests and the action was, therefore, withdrawn. A new company under the title the United Telephone Company was formed on May 13th, 1880, with a capital of £500,000. Mr. James Brand retained the chairmanship and a general flat rate of £20 was adopted.

By an indenture dated July 12th, 1880, Edison's patent of July 30th, 1877, became vested in the United Telephone Co., Ltd.

The first authentic printed list of telephone subscribers to be issued in London appears to be one issued by the Telephone Co., Ltd., dated April 26th, 1880. A copy of this list has been kindly placed at the disposal of the author by Mr. Alfred Perkins, of Bristol, by whom it has been preserved. The following exchanges (or exchange stations as they were then termed) are mentioned in the list. (1) 36 Coleman Street, E.C.; (2) Leadenhall House, Leadenhall Street, E.C.; (3) Palace Chambers, St. Stephen's, Westminster, S.W.; (4) Law Court Chambers, 40 Chancery Lane, E.C.; (5) East India Avenue, E.C.; (6) Leather Exchange, Bermondsey, S.E.; (7) Hop Exchange, Southwark Street, S.E.

Some of these appear to have been projected exchanges and were not actually giving service at the time the list was issued.

The following provincial exchanges were mentioned as having been established: Manchester, Liverpool, Glasgow, Birmingham,

Sheffield, Bristol, Leeds, Dundee, Edinburgh, Bradford, Halifax, Leith, Sunderland, Greenock, Belfast, Newcastle-on-Tyne, etc. The list contains the names of 407 subscribers, but no exchange numbers were quoted. The names of 265 institutions, firms, and individuals situated in various parts of the country for whom private telephone lines had been erected by the company and its agents were included. There were also eighteen testimonials in the form of letters, some of which are interesting and are, therefore, included in Appendix A. Three drawings of telephones were given as follows :—

A. Combination Switch Bell, Ringing Button and Transmitter with one telephone.
B. Switch Bell with Button and pair of telephones.
C. Improved Ebonite Telephones.

" A " was at that time the latest form of telephone instrument adopted by the company and is illustrated in Fig. 13.

CHAPTER III

THE UNITED TELEPHONE COMPANY IN LONDON, 1880–1889

THE directorate of the newly-formed United Telephone Company comprised Mr. James Brand, formerly chairman of directors of the Telephone Co., Ltd., who continued in the same capacity for the United Company, Mr. James Staats Forbes, vice-chairman, and Messrs. J. H. Agnew, J. W. Batten, Dillwyn Parrish, and Colonel Gouraud, with Mr. Joseph B. Morgan as managing director.

The fusion of the two companies naturally involved some reorganisation of staff and co-ordination of forces; under Mr. Morgan's direction the control of engineering work was vested in Mr. C. J. Phillips, electrician, and Mr. Thos. Fletcher, engineer; these two gentlemen assumed charge respectively of the electrical or internal equipment and the line or external plant, including construction, maintenance, and management of staff. The internal or apparatus work for the whole of the Metropolis was managed as one district with its centre of administration at 36 Coleman Street, but for external work the area was divided into five districts—City, West End, South, London Docks and East India Docks, Victoria Docks and further East, in charge respectively of Messrs. Carlisle, Turner, Spagnoletti, A. R. Bennett, and Perkins, all acting under the direction of Mr. T. Fletcher. A little later a sixth, "North," district was placed in charge of Mr. Shorter.

It may perhaps have been anticipated that the amalgamation of the two companies would remove many difficulties arising out of competition and the exploitation of rival patents, and smooth the way for uninterrupted development of the telephone service, but the United Telephone Company were not long permitted to pursue a course of undisturbed progress, and were soon involved in further troubles and difficulties, which engaged their attention to the detriment of the telephonic development of the Metropolis.

A most important legal event in telephone history and one which markedly affected the activities of the telephone business and exercised a lasting influence on the progress of the telephone in this country happened shortly after the formation of the United Telephone Company.

During the period of development of the telephone systems of the two parent companies, the attention of the Government had been directed to the future possibilities of the telephone in relation to the telegraph service. An action was entered against the Edison Telephone Co. of London, Ltd. Information was filed by the Attorney-General on behalf of the Crown on November 27th, 1879, but the action was not commenced until November 29th, 1880. In the meantime, the Edison Telephone Company had ceased to exist and service was therefore accepted by the United Telephone Company.

There is little doubt that the United Telephone Co. were confident of success and they issued statements to that effect prior to the hearing of the case, but there appeared to be some public apprehension that the telephone company might fail and that the telephone itself would disappear with them.

Some held the conviction that a message communicated through the medium of the telephone was not a telegraph message and could not possibly be held to infringe the monopoly of the Postmaster-General; the wise, however, refrained from incautious prophecy as to what the judgment would be.

Notices were given for the following gentlemen eminent in the domain of electrical science and its application to attend the court as witnesses :—

For the telephone companies :—

Edward Pleydell Bouverie, Arnold Henry White, James Brand, Wilfred Tudor Johns, Sir William Thomson, George Gabriel Stokes, John Tyndall, John Hall Gladstone, George Carey Foster, John Ambrose Fleming, Baron Julius de Reuter, Robert Stevenson Symington, Baron Rayleigh, and John Hopkinson.

For the Attorney-General :—

Charles Henry Bennett Patey, Edward Graves, William Henry Preece, Robert Sabine, Cromwell Fleetwood Varley, William Ladd, Sir Charles Tilstone Bright, Josiah Latimer Clark, David Edward Hughes, William Henry Barlow, Warren de la Rue, Sir George Biddell Airy, William Grylls Adams, Charles William

Siemens, Stephen Mitchell Yeates, Amos Moreny Vereker, William Spottiswoode, and Edward Alfred Cowper.

The case was heard in the Exchequer Division of the High Court of Justice at Westminster Hall, the judges being Mr. Baron Pollock and Mr. Justice Stephen.

Connection was established between the court and the United Telephone Co.'s exchange at Palace Chambers, Westminster, by means of Edison's loud-speaking telephone and Bell's telephone, and a selection of Post Office apparatus was displayed upon a table within the court.

The Act of Parliament of 1863, relating to the powers of the telegraph companies which carried on the telegraph business before its acquisition by the State in 1870, defined the telegraph as follows :—" The term ' telegraph ' means a wire or wires used for the purpose of telegraphic communication with any casing, coating, tube or pipe inclosing the same, and any apparatus connected therewith for the purpose of telegraphic communication." The Act of 1863 was embodied in the Act of 1868, which empowered the Postmaster-General to "acquire, work and maintain electric telegraphs." In the third section of the Telegraph Act of 1869, which amended the Act of 1868, it was stipulated that " the term ' telegraph ' shall, in addition to the meaning assigned to it in the Telegraph Act, 1863, mean and include any apparatus for transmitting messages or other communications by means of electric signals. The term ' telegram ' shall mean any message or other communication transmitted or intended for transmission by a telegraph."

Clause 4 of the Telegraph Act of 1869 provided that " The Postmaster-General shall from and after the passing of this Act have the exclusive privilege of transmitting telegrams within the United Kingdom of Great Britain and Ireland and shall also within the kingdom have the exclusive privilege of performing all the incidental services of receiving, collecting or delivering telegrams except as hereinafter provided." The exceptions were " Telegrams in respect of the transmission of which no charge is made transmitted by a telegraph maintained and used solely for private use." Telegraphs belonging to corporations or companies were also exempted on condition that " no money or valuable consideration " be charged, and telegrams " transmitted with written licence or consent of the Postmaster-General " were also excepted

The Attorney-General, on behalf of the Postmaster-General, in effect claimed that the wires and apparatus of the telephone company were telegraphs within the meaning of the Telegraph Acts, and that messages or other communications transmitted by means of any such wires and apparatus were telegrams within the meaning of the same Acts. Also that the transmission, by or with the aid or permission of the company, by means of any such wires and apparatus, of messages or other communications, upon terms of payment to be made to the company, was an infringement of the exclusive privilege conferred upon the Postmaster-General by the Telegraph Act of 1869; and the Attorney-General asked that the company be restrained from continuing these alleged illegal practices.

Experiments were conducted in court with the company's telephone, and a message was transmitted to their lordships from the Palace Chambers exchange.

The case lasted five days and judgment for the Crown was delivered on December 20th, 1880.

The court held that Edison's telephone was a "telegraph" within the meaning of the Telegraph Acts, 1863 and 1869, although the telephone was not invented or contemplated in 1869; also that a conversation through the telephone was a "message" or at all events a "communication transmitted by a telegraph" and therefore a "telegram" within the meaning of those Acts; and that, since the company made a profit out of the rents, conversations held by subscribers through their telephones were infringements of the exclusive privilege of transmitting telegrams granted to the Postmaster-General by the Act of 1869.

Mr. Webster, defendants' counsel, after judgment was announced, prayed that the operation of the injunction might be stayed pending an appeal and the Attorney-General made the following announcement:—

"My Lord, the Postmaster-General is quite alive to the advantage arising to the public from the invention and care shall be taken that no steps shall be taken to stop it."

There appeared now to be three possible methods of dealing with the telephone question. These were as follows:—

(1) The Government itself to undertake the telephoning of the United Kingdom.

(2) The Government to authorise approved individuals or

firms to undertake the telephone business upon terms to be decided upon.

(3) The telephone to be abandoned in this country as a means of communication.

It was scarcely to be contemplated that a contrivance of such promise, and with such possibilities as the telephone even at that time exhibited, should cease to exist altogether, and the Government ultimately decided to issue licences to private firms to carry on the telephone business under certain conditions, one of which was the payment to the Government of a Royalty amounting to 10 per cent. of the gross receipts from subscribers' rentals.

The judgment delivered in the case of the Attorney-General *v.* the Edison Telephone Co., Ltd., was no doubt a bombshell to the United Co. and other firms who by this time had entered into the telephone business in various parts of the country. The ruling of the court virtually vested in the Government complete control over the telephone business, a verdict probably not anticipated by the United Co. or other firms who had established telephone service. Appeal to the High Court against the judgment given was, however, not made owing to the possibility of the judgment being upheld, the heavy exense which would be entailed, and the fact that the Government had signified its willingness to permit the United and other companies to continue their businesses under Government licence.

The views held by the United Telephone Company as to the attitude of the Government regarding the telephone question, and the results of the litigation in which the company had been concerned, are indicated by a passage which appeared in the report of the directors of the United Telephone Company for the year ended April 30th, 1881, and which read as follows :—

" The litigation with the Company initiated by the Authorities for the vowed and anomalous purpose of protecting the Postmaster-General's monopoly of telegraphic communication resulted in a judgment of the Court of First Instance adverse to the telephone companies. This judgment appeared to rest upon the most subtle technical arguments, and to be supported by such a shamed interpretation of somewhat general words in an Act of Parliament as was repugnant to an ordinary sense of fair dealing. It was satisfactory to the inventors and promoters of telephonic communication to find that this judgment, although

it may be technically right, was pretty universally condemned by the leading organs of the Metropolitan and Provincial Press as being very questionable on the grounds both of morality and expediency. It may be desirable to protect a monopoly, but hardly by such means as appropriating useful inventions without adequate compensation, or placing obstructions in the way of their general and easy application to the wants of the public.

"As a result of the judgment before adverted to, negotiations with the Post Office, which had been suspended during the legal proceedings, were re-opened and a compromise was effected, based upon the Company's waiving their right of appeal and accepting the position of licensees of the Post Office, a course which seemed to be preferable to continued and costly litigation.

"An agreement upon this basis has been executed and is now in operation. Under this the Company are to pay to the Post Office 10 per cent. of their gross receipts from all exchange business carried on within a radius of five miles of the General Post Office, London. There are a great number of conditions and limitations imposed which tend greatly to restrict the use of the telephone for ordinary business purposes. From the point of view of the Authorities of the Post Office this may, no doubt, be necessary and justifiable. The directors do not complain of it. On the contrary they have to acknowledge that so far as their negotiations with the Department have already gone they have been met in a spirit of as enlightened liberality as could fairly be expected when it is remembered by what considerations the Authorities must be hampered in their desire to protect the Post Office Telegraph Monopoly acquired at so great a cost. But the Board believe that experience will speedily prove the great superiority for many purposes of the telephone over the telegraph in facility of transmission, despatch and economy, and that it must be soon largely employed by the Post Office itself as a useful and indispensable auxiliary to their important business."

In January, 1882, Mr. J. E. Kingsbury published a small book entitled "The Telephone in Principle and Practice, its Origin and Development," and he commented therein upon the situation as it appeared at that time.

There was indication, however, that the Government itself intended to enter into the field of telephony and establish public telephone service, for, immediately upon judgment being given in the case of the Attorney-General *v.* the Edison Telephone Company on December 20th, 1880, an announcement was issued to the effect that the Post Office was prepared to enter generally into the business of supplying the public with means for telephonic

intercommunication by establishing telephone exchanges. The Post Office was, however, destined to meet with strenuous opposition. The United Telephone Company were now in possession of the master patents, and, smarting no doubt under the ill-treatment they apparently considered they had received at the hands of the Government, and annoyed at the turn which events were taking, they retorted by announcing their firm intention rigorously to uphold their patent rights and threatened to take proceedings (which, as will be seen in a later chapter, they certainly did when the occasion arose) against all and sundry who attempted an infringement of their patents.

Probably the Post Office was, to some extent, influenced by the superior position occupied by the United Telephone Company in this respect; furthermore, the United Company took all possible steps to prevent the Post Office from securing telephone instruments manufactured under the patent rights which they held. The Post Office, however, did not at this time carry out its announced intention of instituting telephone exchange service, except, as will appear later, in a very moderate degree.

The following three advertisements which appeared in juxtaposition in the *Electrician* for December 25th, 1880, have an interest as bearing upon the patent situation at this time.

TELEPHONE INTERCOMMUNICATION

The POST OFFICE has for some time provided a means whereby the Renters of wires into Postal Telegraph Offices may be placed at will in DIRECT COMMUNICATION with each other.

Such a system has been in operation in Newcastle-on-Tyne, Hull, Middlesbro', Stockton and other Towns for several years.

The instrument used in these cases up to the present time has been the A B C instrument. Henceforward, in order to meet the convenience of the public, the Post Office will be prepared to provide for such a system either the A B C or the Telephone instrument.

In the case of the telephone instrument, the annual charge to each Renter in London will be £15 if his premises be within half a mile of the Telegraph Office, £19 if they be more than half a mile, but not more than a mile distant, and at proportionate rates for greater distances.

The Renters will not only have the facility afforded them of communicating direct with each other, but they will also be enabled to send messages by wire to the Telegraph Office to be thence transmitted at the ordinary charge to other towns.

Application should be made to the Secretary, General Post Office; and when several persons in any one neighbourhood have agreed to take wires, immediate steps will be taken to establish a system of intercommunication by Telephone instruments.

By Order of the Postmaster-General.

December 1880.

. . . . . .

Telephones.—The attention of the Directors of the United Telephone Co., Ltd., having been called to certain Advertisements by the Postmaster-General offering to supply the public with Telephone Instruments in connection with private wires and upon the exchange system, Notice is hereby given that the Patent Rights in this country of Professor Graham Bell and Mr. Thomas Alva Edison are the exclusive property of the United Telephone Co. (Limited) and that Proceedings will be taken against All Persons using any form of Carbon Transmitter, or any form of Magneto or Electro-Chemical Receiver, whether such Telephones are supplied by the Postmaster-General or by any other person not authorised by the United Telephone Company (Limited), all such Transmitters and Receivers being infringements of the said Patents.

By order of the Board,

James Brand, Chairman.

Dated this 21st day of December, 1880.
36 Coleman Street, London, E.C.

. . . . . .

Telephones.—With reference to an advertisement, signed by the Chairman of the United Telephone Company (Limited) threatening legal proceedings against the users of Telephones supplied by the Postmaster-General, the Gower Bell Telephone Company (Limited) hereby give notice:—

1. That H.M. Postmaster-General has contracted with this Company for large supplies of Gower Bell Loud-Speaking Telephones, having found this to be the only form of telephone which has sustained the official tests for efficiency, simplicity and permanence of operation.

2. That the telephones sold by this Company are manufactured under agreement with the United Telephone Company (Limited) and that that Company has been, and is directly, interested in the profits arising from such sales.

By order

J. A. Mays, Secretary.

No. 9 Great Winchester Street, London, E.C.
22nd December, 1880.

Such then were the circumstances associated with the telephone service in 1880–1881. From what has been said, it will be apparent that at this time the telephone service was not administered under very happy auspices, and relations between the telephone companies and the Government continued to be very much strained.

The financial result of the first year's working of the United Company was not altogether encouraging, but in view of the somewhat embarrassing circumstances in which business had to be carried on, it is perhaps surprising that the results were as good as they were.

The directors' report of the first year's working of the company was published on April 30th, 1881. Revenue for the year was £20,644 10*s.* 6*d.* and the expenditure chargeable to revenue account £20,273 12*s.* 11*d.*, leaving the small balance of £370 17*s.* 7*d.* Although the directors regarded the result of the year's working as exceedingly satisfactory when all the circumstances were taken into account, the following reasons were advanced for the small margin of profit secured.

"Following upon the fusion of the Bell and Edison companies the two establishments had to be re-organised and brought into harmonious working, a uniform system had to be established, and means adopted to improve the conduct of the business taken over from the two companies. This involved much time, labour, and expense; and besides, made it prudent to abstain from seeking new subscribers until the reasonable wants of the older ones could be fairly met.

"The position assumed by the Post Office, and the consequent doubts thrown upon the power of the company to furnish telephone communication, also tended, for obvious reasons, to impede the progress of the company. In an entirely novel undertaking like that of the company, where a special kind of directing and manual skill has to be more or less created, the progress, to be sound, must at first be comparatively slow, otherwise much needless expense of time and money may be incurred; and much that has been done undone. In any event an abnormal relation between cost and income must result in the first year or two of such a business. This is a point especially to be borne in mind in judging of the future of the company. The expenditure of the first year has about equalled the receipts, but the company are now in a position to invite and conduct satisfactorily a much larger amount of business, which additional business will be carried on at a very small additional cost, and the profits therefore largely increased."

As at April 30th, 1881, there were 914 exchange subscribers and 186 private lines associated with the company's system.

The first licences issued by the Postmaster-General were for certain circumscribed areas in different localities, the areas being defined by a circle with a radius of four or five miles from the centre of a town. The United Company secured licences in 1881 and in London their operations were limited to a radius of five miles from the General Post Office. The licences issued, together with the licences subsequently granted to other private companies formed at a later date, were all for a term of 31 years from January 1st, 1881.

A draft copy of one of the early licences to conduct telephone exchange business appears as Appendix B.

The United Telephone Company upon their formation proceeded as vigorously as circumstances would permit to develop their system in the Metropolis. They already possessed the eight exchanges established by the two former companies, viz.: 36 Coleman Street, Leadenhall Street and Westminster (Bell), 11 Queen Victoria Street, 77 Cornhill, Eastcheap, Chancery Lane and Heddon Street (Edison), serving at the time of their acquisition upwards of 400 exchange subscribers.

As the subscribers served by these eight exchanges increased in number, which they did rapidly, and the popularity of the telephone service grew, the necessity for augmenting the switching accommodation which existed soon became apparent.

Coleman Street, the original exchange, was the first to be subjected to the process of extension, and the opportunity was taken of introducing an important modification in the equipment and method of operating which resulted in decided improvements.

As there were originally only six pairs of horizontal bars on each connecting panel of the slipper jack switchboard wired to each operating table, it will be obvious that twelve simultaneous conversations only could be conducted, *i.e.*, six via each table, and consideration was therefore given to the provision of additional operating tables. At the suggestion of Mr. J. S. Holt a substantial modification in the circuit arrangements and method of operating was eventually made and the improvement reduced considerably the number of operating tables which would otherwise have been required.

The wiring between the horizontal bars of the connecting sections

and the keys on the operators' tables was abolished, each table being provided with a single cord and plug to enable connection to be made with any calling or wanted subscriber's circuit for answering or calling purposes, connection between two subscribers being established by means of single cords provided at each end with plugs suitable for insertion into the subscribers' slippers.

At the same time, the indicators appear to have been removed from their position in the circuit between the lower plate of the slipper and earth and to have been connected in the line circuit on the line side of the slipper so that, when a connection between two subscribers was made by means of a connecting cord, both the calling indicators remained in series in the speaking circuit. In this way provision was made for receipt of a clearing signal by the subscriber depressing the ringing button on termination of conversation.

The necessity for the horizontal bars thus disappeared and consequently in later equipment of the slipper-jack type they were not provided. Subsequent to the modifications described, the Coleman Street exchange became the largest of the slipper-jack exchanges.

A further modification which was made somewhere about this time was in the introduction of what was known in London as the " knife-jack."—It is necessary here to explain that, during the latter part of the period in which so-called slipper-jack equipment was employed, the meanings of the terms " jack " and " plug " were not synonymous with those which they convey to-day.

A jack was known as a slipper and a plug as a jack. This, of course, did not apply to the plug of the Edison switchboard, which was always termed a " peg." The term " slipper-jack," as then used to indicate the type of equipment, meant, in present day parlance, equipment in which a jack was used in conjunction with a plug.

The " knife-jack " really took the place of the horizontal brass strips of the Williams switchboard and was fitted at the end of the flexible cord connected to the operator's speaking set. As the word knife implies, it was merely a blade fitted in a handle of insulating material. In answering a call the plug at one end of a connecting cord was inserted into the jack (or slipper) of the line of the calling subscriber, the similar plug at the other

FIG. 13.—Silvertown Telephone Instrument with Blake transmitter as employed by the Telephone Company, Ltd.

(From a photograph supplied by Mr. F. McClarence.)

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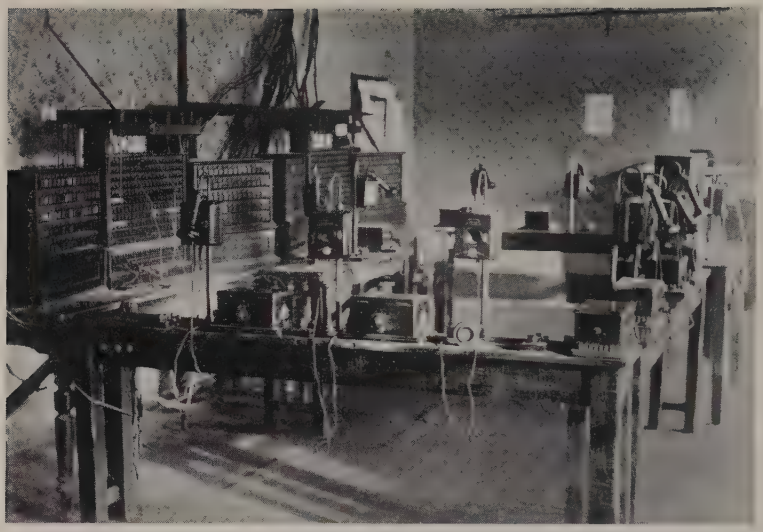

FIG. 14.—Slipper-jack Switching Equipment, Palace Chambers, Westminster, London, 1883.

(From a photograph loaned by the late Mr. J. W. Ullett.)

FIG. 15.—Twenty-five-line Section of Edison Switchboard from 11 Queen Victoria Street, London, E.C.

(From a photograph by the Author).

[*To face page* 53.

end being meanwhile free, and the blade of the knife-jack inserted between the plug of the connecting cord and the spring of the slipper, thus placing the operator in direct communication with the subscriber. After the number of the subscriber to be called was ascertained the free plug of the connecting cord was inserted into the corresponding jack, and the ringing was effected from the operator's instrument through the knife-jack and through both subscribers' lines simultaneously. As soon as the operator observed that the two subscribers were conversing, the knife-jack was withdrawn, communication being maintained through the connecting cord. The knife-jack was then available for answering other calls, which were similarly dealt with.

An illustration of the Westminster slipper-jack exchange from a photograph supplied by the late Mr. J. W. Ullett, of Nottingham, appears in Fig. 14.

Applications for telephone exchange service were now being received from numerous quarters and it was evidently possible to secure remunerative business in other parts of the Metropolis as yet untouched by the extension of the facilities for exchange service further afield; the United Company therefore decided to open additional telephone exchanges in various parts of London. Incidentally advantage would also be gained in the relief which would be afforded to exchanges already established by diverting to the new exchanges some of the more remotely situated subscribers and in the shortening of their lines, a process which has since been repeated on numerous occasions and has become a recognised feature of telephone development.

The necessary arrangements were quickly made, suitably situated premises were secured, and exchanges appear to have been opened in the following order :—

6 East India Avenue
Commercial Sale Rooms, Mincing Lane
Hop Exchange Building
67 Cow Cross Street, Smithfield
King's Cross
East India Dock
Edgware Road

before the close of the year 1882, so that by that date there were probably fifteen exchanges in London.

The United Company continued to use both types of switchboard which have already been described as adopted by the parent companies.

The exchanges at Mincing Lane, Smithfield, and Edgware Road were equipped with switchboards of the slipper-jack type, while, for the remainder, Edison switchboards were employed.

It is not clear whether the excess of Edison over slipper-jack switchboards in use in London at this time may be taken as an indication that the performance of the Edison board was considered generally to be superior to that of the slipper board; probably the question of facility for securing early delivery had something to do with the selection, nevertheless at this time the Edison board, in so far as its use in London was concerned, was in the ascendancy.

The telephone service in London was now growing rapidly, and important problems arising out of the expansion of telephone exchange systems had to be faced.

One of the most important, and perhaps the most difficult of all, was the problem associated with the extension of the early exchanges. Orders for new connections continued to be received and had to be catered for; available exchange equipment fast became exhausted; it was highly undesirable that development should be retarded and revenue refused by the adoption of a policy of declining new orders. Hence by some means arrangements had to be made to provide the necessary equipment to ensure that whatever demands for telephone service were received from the public should be satisfactorily met.

The diagram given in Fig. 11 illustrates the type of Edison switchboard utilised for small exchanges in the Provinces, which accommodated 24 exchange lines only. For larger exchanges in London where the Edison peg switchboard was employed the principle adopted was precisely the same, but, when the number of lines exceeded the number which could be accommodated on one section, the equipment was increased by fitting a second similar section horizontally alongside the first, and coupling together the respective horizontal bars. The photograph reproduced in Fig. 15 shows one of the complete sections of the Edison peg switchboard at one time in operation at the historic exchange established by the Edison Company at 11 Queen Victoria Street, London. It will be seen that the number of vertical bars is 25,

and this number therefore represents the number of lines which could be accommodated on one such section which extended horizontally over a distance of 18 inches. For more than 50 subscribers the sections were still further extended horizontally, as circumstances demanded, and, when the number of calls to be simultaneously maintained became such that the twelve horizontal bars contained in one section was insufficient, further sections were provided below or above the existing sections, the respective vertical or subscribers' bars being coupled together in order that the additional 12 horizontal bars provided might be made available for them.

Two horizontal sections accommodating 50 lines and extending over a distance of 3 feet comprised an operator's position. Figs. 16, 17, and 18, which will be referred to again later, show exchanges with Edison switchboards assembled in the manner indicated.

It will be apparent that so long as the circuits of the two subscribers to be placed in communication were terminated at the same position, *i.e.*, were within reach of the operator, no difficulty was presented in completing the connection, but, when the subscriber to be called was connected to a position other than that at which the call originated, as there was but one point of access to each subscriber's line, serious operating difficulties were at once created. Such connections were dealt with by the passage of the necessary particulars verbally between the two operators concerned.

One of the principal difficulties was that an operator was unable to ascertain, without verbal inquiry, whether or not a wanted subscriber's line was engaged at a position other than the one she occupied.

In his book, "The Telephone and Telephone Exchanges," Mr. Kingsbury deals with the developments which eventually led up to the production of the multiple switchboard embodying a test system and describes how Mr. Leroy B. Firman surmounted this difficulty. Mr. Firman's United States Patent No. 252576, dated January 17th, 1882, described a system which he employed in Chicago, in which points of connection for all the subscribers in the exchange were multipled throughout two or more switchboards, at either of which any two lines might be connected together. The purpose which the test system now serves was accomplished by exhibiting the subscribers' numbers upon a

board exposed to the view of all the operators in the room. An attendant in charge of the board was advised by the operators of all connections made by them, and he excluded from view the engaged numbers by hanging over them a suitable mask. By scrutinising the board operators were thus enabled to ascertain whether a number for which inquiry had been made was engaged or not. No device of this description was, however, introduced in London; reliance was still placed upon the operators' passing to and fro by word of mouth the necessary injunctions as to their requirements.

The state of confusion which ensued at busy periods bordered on pandemonium, and can no doubt be imagined.

An illustration which appeared in the *Graphic* for September, 1st, 1883, is of interest, as it includes pictures of two London exchanges, and generally portrays the conditions under which exchange switching was effected, and the success which had been achieved by that date in providing telephone intercommunication. The illustration is reproduced in Fig. 16, by kind permission of the editor of the *Graphic*.

The illustration includes :—

(1) A picture of a switchroom * (Westminster) of a Central Office worked on the slipper board system, *i.e.*, on the system adopted by the Telephone Co., Ltd.

(2) A view of a switchroom * (Eastcheap) of a Central Office worked on the Peg Board System, *i.e.*, the system adopted by the Edison Telephone Co. of London, Ltd.

(3 and 4) Two parties carrying on conversation between an office in London and a room in Brighton, probably published in anticipation of the opening of the London-Brighton trunk line.

(5) A general view of the Head Central Office of the United Telephone Company, 36 Coleman Street, London.

(6) A view of a reporter transmitting from the House of Commons a report to the office of *The Times*.

The following is an interesting description of a telephone exchange which appeared in the *Pall Mall Gazette* for December 6th, 1883 :—

"What, then, is a telephone exchange station? We will take the East India Avenue, in the City, as an average sample. From

* These exchanges have been identified for the author by Mr. A. Watts.

FIG. 16.—Two London Telephone Exchanges. Reproduced from an illustration in the *Graphic*, September 1st, 1883, by permission of the Editor.
(*From a print loaned by Mr. J. H. Storrie.*)

[*To face page* 56.

FIG. 17.—Edison Switchboard at the "Hop" Telephone Exchange, Southwark Street, London, S.E.

(From a photograph lent by the late Mr. J. W. Ullett.)

[*To face page* 57.

the lofty roof of one of the houses of that sombre court rises a derrick, a square structure of wrought-iron bars 30 or 40 feet high by 8 or 10 feet wide, and looking like the upper portion of a skeleton lighthouse, very rigid and very transparent. This edifice is surmounted by a lightning conductor; you ascend it by a perpendicular ladder, and, pausing on its upper story—for it is divided into two floors—you look round from your airy perch to find that what appear innumerable wires radiate from your transparent cage in every possible direction over the dirty housetops of the City. Most of these wires are bare and unenclosed; others are in cables containing each twenty wires. Each of them is lettered and numbered, and a cupboard on the derrick contains an apparatus for testing them. So much for what is above the roof. Below, in the attic, is a room occupied by eleven young ladies. The 271 wires, which represent the subscribers of the East India Avenue Exchange with 46 trunk and other direct wires, are guided down from the derrick above into neat mahogany cabinets or cases, in front of which the young ladies are seated. The alert dexterity with which at the signal given by the fall of a small lid about the size of a teaspoon the lady hitches on the applicant to the number with which he desires to talk is pleasant to watch. On the day of our visit there had been in this one office no less than 2400 calls. Here, indeed, is an occupation to which no 'heavy father' could object; and the result is that a higher class of young women can be obtained for the secluded career of a telephonist as compared with that which follows the more barmaid-like occupation of a telegraph clerk."

By 1883 several of the Edison exchanges which have been named had developed to appreciable size, notably Queen Victoria Street and Avenue, which accommodated some four to five hundred subscribers' lines each in addition to the necessary junctions or trunks, and the methods of operating in Edison exchanges of such size, as also indeed in exchanges of the slipper-jack type by the means which were available, left much to be desired.

The late Mr. J. W. Ullett, of Nottingham, kindly allowed the author to reproduce a number of photographs which he had preserved, amongst them being one of the Edison switchboard at the "Hop" Exchange, London, as it existed in 1883, shown in Fig. 17.

A photograph, taken about the same date, of the Avenue Exchange, of similar type, for which the author is indebted to Mr. H. Davis, of West Croydon, appears as Fig. 18. These two

photographs give an excellent impression of the general assembly of an Edison switchboard as employed in London, for the larger exchanges, at the period in question. The general arrangement and details of some of the various parts may be gathered from an examination of these two illustrations, which show the switchboards as they existed shortly before their replacement by boards of the multiple type.

In the first form of telephone instrument employed in this country, combining the Blake transmitter and the Bell receiver, previously referred to in Chapter II, and illustrated in Fig. 13, the transmitter was contained in the same case as the trembler bell used for calling purposes. Some trouble was experienced in maintaining the Blake transmitters in this type of instrument in satisfactory adjustment, and it was concluded that the vibration of the trembler bell contributed to its derangement. Shortly after its formation, therefore, the United Telephone Company introduced a new design of instrument in which the transmitter was accommodated in an entirely separate case from the call bell. Both wall and table types of instrument were arranged, and in Figs. 19 and 20 they are respectively illustrated. These illustrations, as well as Fig. 13, have been prepared from photographs of instruments retained as museum specimens by the National Telephone Company, and now preserved in the museum of the Post Office Engineering Department at the General Post Office, London. Fig. 19 shows the wall type of instrument in question. It comprised two separate cases, one containing the Blake transmitter, and the other the call bell switch-hook and ringing button, both mounted upon one backboard.

Fig, 20 shows how the parts were assembled to form one of the first forms of table instrument in which the separate cases, containing respectively the transmitter and call bell, were mounted back to back upon a pedestal fitted with a wooden base. These two instruments were known as the " St. George " type.

Instruments of this design may be seen in the illustration (Fig. 21), reproduced from a circular issued by the United Telephone Company and loaned for the purpose by the late Mr. J. W. Ullett.

From the overhead structure which surmounted the roof of 36 Coleman Street, the first overhead wires associated with the telephone exchange service of London began to radiate, and it

FIG. 18.—Edison Switchboard at the United Telephone Company's "Avenue" Exchange, East India Avenue, London.

(From a photograph loaned by Mr. H. Davis.)

FIG. 19.—Telephone Instrument, wall type, with Blake transmitter and call bell in separate cases, as employed by the United Telephone Company.

(From a photograph supplied by Mr. F. McClarence.)

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FIG. 20.—Telephone Instrument, table type, with Blake transmitter and call bell in separate cases, as employed by the United Telephone Company.

(*From a photograph supplied by Mr. F. McClarence.*)

[*To face fig.* 21.

FIG. 21.—Example of the practical use of the Telephone from a Trade Circular issued by the United Telephone Company.

(Reproduced from a circular lent by the late Mr. J. W. Ullett.)

[*To face fig.* 20.

FIG. 22.—Standard on roof of 36 Coleman Street, London, E.C.
(From a photograph by Mr. J. N. Hill.)

[*To face fig.* 23.

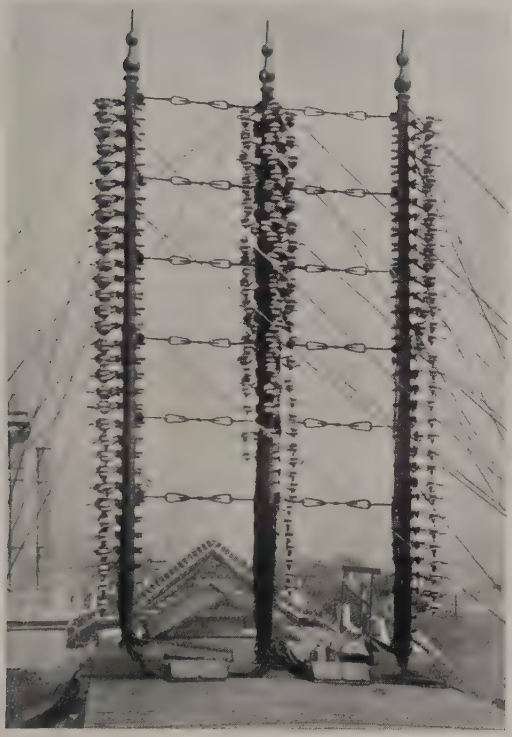

FIG. 23.—Structure on roof of United Telephone Company's Eastern Exchange, London, 1883.

(From a photograph loaned by the late Mr. J. W. Ullett).

[*To face fig.* 22.

FIG. 24.—Derrick for support of Overhead Wires, Chancery Lane, London.

(From a photograph by Mr. Alfred Perkins.)

[*To face page* 59.

was here that the huge overhead system, which was eventually built up in association with the exchange telephone service in London, had its beginning. At first the length of the lines was limited to a few hundred yards from the exchange, but as the service developed the length of line increased, and the tentacles of the telephone service began to spread themselves abroad.

The frontispiece and illustration reproduced from the *Graphic* for September 1883 in Fig. 16 show views of the Coleman Street premises with the overhead structure upon the roof, and Fig. 22 is from an actual photograph of the same structure taken from a neighbouring roof some time later.

At other exchanges opened in different parts of London, similar conditions prevailed and it became necessary to provide lines interconnecting the several exchanges in order to permit of conversation between subscribers on different exchanges. In this way was inaugurated the system of junction lines which quickly became an important feature in the telephoning of London.

The overhead wires first generally used in London were composed of 3/16 stranded galvanised iron wire. Arms, as used to-day, were not at first commonly employed; the wires were attached to shackle insulators secured direct to the uprights of the roof poles, one above another after the manner illustrated in Fig. 23 (from a photograph loaned by the late Mr. Ullett), showing a structure made up of three tubular iron roof poles, braced together and suitably stayed, erected on the roof of the Eastern Hotel, Limehouse, and supporting the wires entering the Eastern Exchange.

The increasing number of wires which had to be provided as the service grew soon introduced difficulties in procuring means for their accommodation, and structures of various forms were erected. Fig. 24 is from a photograph by Mr. A. Perkins of the heavy iron derrick erected by the United Telephone Company on the roof of Lonsdale Chambers, 27 Chancery Lane, supporting the wires required for giving service to the exchange originally established there by the Edison Telephone Company. In due course, several structures of similar design were erected on some of the roofs of the City, and some of them still exist.

The insulated wire used in those days for leading in at exchanges, and for leads at subscribers' premises, was composed of single 18/7½ gutta percha-insulated copper wire.

Early aërial cables in London were formed of several of these gutta percha insulated conductors bound together by hand with prepared tape. But the number of wires increased, accommodation on existing roof structures became appropriated to use, and the need for a more substantial form of aërial cable became somewhat pressing; aërial cables were therefore made up by hand, by laying together twenty single 18/9 gutta percha insulated wires with a core of 3/16 galvanised iron stranded wire, inserted as a palliative for induction, and binding them securely together with prepared tape. At a still later date, as the demand for aërial cable increased, the manufacture, in quantity, of gutta percha insulated cable was undertaken in the factory by the Silvertown and Henley companies (the salient features of such cables are given in Chapter XVI).

At 36 Coleman Street, the gutta percha insulated wires, which were employed for leading in the subscribers' lines from the open wires to the exchange, were at first terminated direct upon the switchboard; but, as the number of incoming lines increased, the need for intermediate testing facilities became apparent, and need was provided in the form of a large square board of teak, fixed vertically, through which large brass terminals were fitted 2 inches apart. The single gutta percha-covered leads from the roof structure were terminated on the one side, and, from the other, cables made up of single cotton-covered paraffined wires, bound together to form a cable, were run to the switchboard. This arrangement provided the facilities desired, but, in course of time, additional wires were provided and the mass of insulated conductors terminated on the line side of the terminal board became very bulky, so that access to the terminals on the upper portion became well-nigh impossible.

Consequently, when it was decided to provide similar facilities for the Avenue Exchange a different and improved device was adopted. The arrangement was situated immediately below the roof, and consisted of two long boards fixed horizontally and parallel one above the other. On the upper board the leads from the roof standard, and on the lower the wires from the switchboard, were terminated on terminals in rows ten deep, cross connecting wires being run between them as required. In this manner the first form of telephone cross-connecting frame or test-board in London came into being.

In 1881 the United Telephone Company experienced opposition and competition in London, created by the formation of the London and Globe Telephone and Maintenance Co., Ltd. The competitive rental for Exchange service was £10 per annum, as compared with the £20 tariff charged by the United Company. The Globe Company acquired premises at Wool Exchange Chambers, Basinghall Street, and opened an exchange there.

The system of working adopted by the Globe Company possessed unique features and displayed originality.

It is of peculiar interest, as it appears to be the first system in which central batteries were used in place of independent batteries on subscribers' premises. Mr. George Lee Anders, who was electrician to the London and Globe Company, devised and patented a system which is described in Patent Specification No. 749, dated February 16th, 1882, and was for "Improvements in Telephonic Exchange Systems and Apparatus." The brief description which follows is taken from the Patent Specification.

The subscribers' instruments comprised a magneto receiver and a Hunnings transmitter connected in series without any induction coil, a call bell, and a switch-hook, the last so contrived that it made a "fleeting" contact to earth when the receiver was removed, and also when it was replaced. The subscribers' lines were metallic circuits.

For signalling purposes a common battery was provided at the exchange, one side being permanently connected to the indicators associated with the subscribers' lines, the other side being earth connected. Separate batteries, also situated at the exchange, were used for speaking purposes.

Fig. 25 illustrates the main features of the system. The connections of the subscribers' instruments and of the exchange switchboard are shown.

Each subscriber's line terminating on the switchboard was provided with a drop indicator, a spring-jack, the springs of which were normally in contact, and a flexible cord terminating in a flat plug, consisting of two metal strips separated by insulation. The speaking battery was connected through a flexible cord to a similar plug, and was applied to the line by inserting the plug associated with it between the normally closed springs of the jack, through which each subscriber's line was connected. The number of speaking batteries, with their associated flexible

cords and plugs, was proportioned according to the probable maximum number of pairs of subscribers requiring communication at the same time.

The switching device proper consisted of a series of pairs of

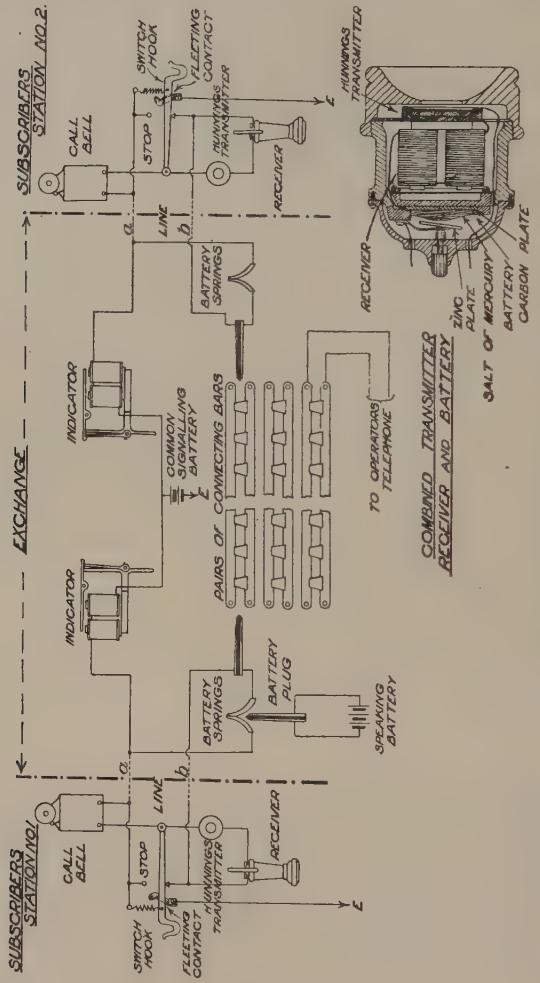

FIG. 25.—System of telephone working devised by G. L. Anders for the London and Globe Telephone and Maintenance Company.

metal bars mounted horizontally on the vertical face of the switchboard. The pairs of bars were slotted at intervals, as indicated in the diagram, to facilitate insertion of the two-way flat plugs. One pair of bars was reserved for the operator's telephone to which they were connected, and the remainder of the

bars served purely as connecting bars, and were not wired to any portion of the apparatus.

The number of pairs of bars provided corresponded with the estimated maximum number of pairs of subscribers requiring to be in communication at the same time, and to the number of speaking batteries with their associated flexible cords and two-way pegs, with the addition of the pair of bars for the central station operator's telephone.

As a subscriber lifted the receiver from the switch-hook, the fleeting contact was momentarily made during the upward passage of the switch-hook, causing a current to flow, from the common signalling earthed battery at the exchange, through the subscriber's indicator, line, and switch-hook to earth, and the calling signal was accordingly given by the shutter of the indicator falling.

The operator thereupon inserted, in the pair of bars to which the operator's telephone was connected, the double-sided plug associated with the calling subscriber's circuit, and also inserted between the closed springs of the battery jack one of the plugs connected by flexible cord to a speaking battery. The former operation placed the operator's speaking set in series with the line of the calling subscriber, and the latter caused a current to circulate in the circuit, and rendered possible communication between the operator and the calling subscriber. The subscriber's requirements being ascertained, the required connection was established by insertion of the plugs terminating their respective circuits into one of the free pairs of connecting bars through which the connection was thereafter maintained. The speaking battery was now in series with the lines of the two subscribers, and served to ring the bell of the subscriber whose attention was desired. When the subscriber answered, the call bell was short circuited by the switch-hook engaging with the metallic stop shown in the diagram, and the battery current was diverted through the transmitter and receiver in series. Communication was thus established. The specification claimed that two subscribers might converse together without the risk of the central station operator overhearing the conversation, but it would appear that the operator might break in on the circuit by plugging into a third plug hole between the two bars by means of which through communication was sustained; such an operation,

however, would probably be attended with a breakdown of conversation between the two subscribers, a contingency depending upon the battery power and the relative resistances of the circuits of the operator's speaking set and of the two subscribers' lines and instruments.

The fleeting contact made by the raising of the switch-hook, when the called subscriber answered, caused his indicator shutter to fall and thus gave to the operator intimation that he had attended to the call. The two indicator shutters were then replaced; restoration by the operator to normal conditions followed upon receipt of the clearing signal, denoted by operation of the subscribers' indicators, caused by the fleeting contact when the subscribers' receivers were replaced.

The same specification includes a description of a combined transmitter, receiver and battery, capable of being held in the hand, and, as the combination is peculiar, a longtitudinal section of the arrangement is included in Fig. 25. The specification claimed as an advantage of this combination "that the sound-waves shall act both upon the receiver and transmitter during the operation of transmitting whereby a louder and clearer articulation is obtained." The combination would involve alternation of its position relative to the ear or mouth, according as reception or transmission was desired, and in view of the inclusion of the novel battery, as implied in the specification, it was not intended for exchange service. On the exchange system, the Hunnings transmitters used were separate from the receiver, and were held in the hand whilst speaking, the idea being that the movement so caused would tend to prevent "packing" by disturbance of the particles of carbon within the transmitter. A photograph of one of the Globe Company's Hunnings transmitters preserved by the late Mr. J. W. Ullett is reproduced in Fig. 27.

The method of working which has been described may be correctly termed a "common battery signalling and central battery speaking system." Its objectionable features may be discerned from a study of the connections given in Fig. 25. It possessed certain features akin to some of those associated with the modern common battery signalling system of the British Post Office, and is also interesting as being the forerunner of the present day central or common battery system, although it is

probable that the latter was devised in entire absence of knowledge of the system invented by Anders.

It should be mentioned that the switching arrangements installed by the Globe Company may have differed from those described in Anders' patent specification, but the essential features of the system were undoubtedly retained.

The period of competition between the Globe Company and the United Company was marked by incidents of an exciting character, and much bitterness of feeling was engendered. The United Telephone Company had a number of open wires crossing the Wool Exchange, where the Globe Company's exchange was situated, and the Globe Company demanded their removal. The United Company took no notice of this demand and, apparently exasperated by their seeming indifference, the Globe Company deliberately caused annoyance to the rival company and their subscribers by faulting the offending wires, throwing other wires across them for the purpose. The trouble did not end there, however, for the Globe Company at intervals disturbed the operators of the United Company and their subscribers by connecting ringing current to the wires. The subscribers were thus involved in the dispute and a general fracas ensued. All kinds of allegations and counter charges as to the tying up and cutting of wires were lodged by the employees of either company against the other, and as *The Electrician* said at the time, " the case alternated between the police courts and the Court of Chancery, the only persons benefiting being the lawyers." The matter was only settled when the United Telephone Company acquired the Globe Company's business and patent rights at a cost of £25,000, the latter undertaking being absorbed on June 24th, 1884.

Mr. C. B. Clay, who was appointed to take over the Globe Company's plant on behalf of the United Company, informs the author that the switchboard was dismantled and the exchange closed. There were comparatively few subscribers to deal with as most of them were duplicates of the United Company's system. The remainder were diverted to other exchanges. This is probably the earliest example of one of the disadvantages of competition in telephone administration where intercommunication facilities were non-existent, viz. the unnecessary duplication of plant.

In spite of the numerous and repeated warnings issued by the Telephone Co., Ltd., and its successor the United Telephone Company, that legal proceedings would be taken against all and sundry who in any way infringed their patent rights, many parties entered upon the construction, sale, and hire of telephones in which the principle of the Bell and Edison patents appeared to have been utilised, and consequently the United Company deemed it necessary to invoke the aid of the Law Courts on many occasions, in order to enforce the rights of patent which they had acquired at such heavy expense.

In the year 1882 cases of litigation respecting telephone patents were of common occurrence, and the United Company entered the courts on their own volition on no less than eight occasions, in all of which they were successful.

The first action was brought by the United Telephone Company against Alexander Maclean, of Edinburgh, on Tuesday, January 24th, 1882, to restrain the defendant from making and selling carbon transmitters and Bell receivers, which, it was claimed, infringed respectively Edison's patent No. 2909 of July 1877 and Graham Bell's patent No. 4765 of December 1877.

Lord M'Laren, the presiding judge, ruled that the complainers were entitled to protection by interdict under both patents and an injunction was granted accordingly.

The year 1882 was of particular interest as regards litigation because one of the most important telephone patent cases, and one of the most interesting law cases respecting patents of any description ever conducted in this country, took place then; it was long known as "The Telephone Case," and it caused considerable interest and some excitement in telephone circles during the period in question.

The case in point was one brought by the United Telephone Co., Ltd., against Messrs. Harrison, Cox-Walker and Co., of Darlington, who were manufacturers for the promoters of the London and Globe Telephone and Maintenance Co., Ltd. The United Telephone Company, who were the assignees of the Bell and Edison patents of December 9th, 1876, and July 30th, 1877, respectively, alleged that the defendants had infringed both these patents by using in the telephones which they sold a receiver known as the Cox-Walker receiver, and another receiver known as the Hickley, both of which, it was maintained,

were infringements of the Bell receiver, also a transmitter known as the Hunnings, which, it was said, was an infringement of the Edison transmitter. An injunction was claimed.

The case came on for hearing on April 24th, 1882, and occupied sixteen days. Judgment was given on May 19th, 1882. Mr. Justice Fry granted an injunction in regard to the first patent (the receiver), but ruled that the Edison patent was invalid because the invention of the phonograph which was described in and claimed by the complete specification was not sufficiently described in the provisional specification. He therefore dismissed the action in regard to the transmitter.

The United Telephone Company lost no time in taking further action in regard to the transmitter, for on May 31st, 1882, that is, twelve days after the decision against them had been made, they filed a petition of disclaimer and memorandum of alteration of certain parts of the specification of Edison's patent, including the phonograph, and on August 16th, 1882, the Attorney-General granted his fiat, allowing the disclaimer upon certain conditions.

The matter did not end here, however, for in due course Messrs. Harrison, Cox-Walker and Co. appealed against the decision of Mr. Justice Fry of May 19th, 1882. This appeal led to a lengthy and very argumentative case conducted in the English Court of Appeal before the Master of the Rolls, Lord Justice Lindley and Lord Justice Bowen.

The case commenced towards the latter end of January 1883, and lasted nine days.

Many eminent scientists and men of the day appeared as witnesses, amongst whom were the following :—

Sir Frederick Joseph Bramwell.
Professor Silvanus Phillips Thompson.
Dr. Alexander Muirhead.
Mr. Ladd.
Professor Dolbear.
Mr. H. W. Dunscombe.
Dr. Stone.
Professor W. E. Barrett.
Professor W. E. Ayrton.
Mr. H. S. Eaton.
Dr. J. Hopkinson.

Sir W. Thomson.
Mr. John Imray.
Mr. Edwards Stebbins Johnson.
Mr. Herbert John Allison.
The Rev. Henry Hunnings.
Mr. Thomas Augustus Watson.

On Tuesday, February 6th, 1883, the Master of the Rolls gave his judgment, which entirely supported Mr. Justice Fry's decision, and on the day following Lords Justices Lindley and Bowen concurred in that judgment.

In respect of the two patents, the United Telephone Company were again masters of the situation and they so continued until the Bell and Edison patents expired on December 9th, 1890, and July 30th, 1891, respectively.

In so far as the transmitter was concerned, Edison's invention now not only possessed the prior claim, but legally Hunnings' instrument was an infringement of it. By many people the view was held that the invention and publication of the microphone by Professor David Hughes should have rightly invalidated the claims of both Edison and Hunnings.

The Electrician, in a leading article published in the issue of that journal for February 24th, 1883, thus commented on the situation :—

"Mr. Hunnings' transmitter is acknowledged to be a very good one; its predecessor is said to be not so good, and in several respects not so serviceable for everyday use. Be this as it may, one thing appears to be certain, that whatever its superiority might have been, the later invention would have been condemned, and the public consequently deprived of its use, because somebody else had contrived an earlier and similar though less useful instrument. This is a case, it seems to us, where patent laws, while very properly protecting the rights of inventors, tend to discourage the efforts of improvers and are thus not conducive to the public interests. It is nowhere suggested that the Hunnings transmitter is a wilful piracy, or even a colourable imitation; on the contrary, some eminent experts have testified to its being a new and independent invention, besides being one of considerable practical utility. By this judgment it is, we suppose, now shut out of the market, and the public are consequently compelled to use another invention whether they like it or not. Probably the public, if they had

any voice in the matter, would disclaim any wish to deprive the first inventor of his rights; but in public estimation rights are simply another word for merits, and on their merits respectively the two inventions, so the public would say, ought to stand."

Purchase by the United Telephone Company of the Hunnings patent removed the disadvantages which attached to the judgment referred to by *The Electrician*, and the same action, it is believed, led Messrs. Harrison, Cox-Walker and Co. to drop their appeal to the House of Lords, which was pending regarding the Cox-Walker receiver.

Subsequent to the judgment delivered on May 19th, 1882, by Mr. Justice Fry in the case brought by the United Telephone Company against Messrs. Harrison, Cox-Walker and Co., but prior to the hearing of the appeal against that judgment, there followed another interesting dispute arising out of the peculiar patent situation which existed at the moment.

Copies of two announcements, typical of many which were published broadcast in the newspapers in 1881 and 1882 by the United Telephone Company, are given below :—

TELEPHONE INFRINGEMENTS.—The DIRECTORS of the UNITED TELEPHONE COMPANY, LIMITED, hereby give notice as follows :—

THE UNITED TELEPHONE COMPANY are the Owners of all the patent rights in this country granted to PROFESSOR ALEXANDER GRAHAM BELL and MR. THOS. ALVA EDISON, relating to the original MAGNETO TELEPHONE and the CARBON TRANSMITTER. All persons are CAUTIONED against manufacturing, selling, supplying, or using any of these instruments, except under the license of the Company.

THE UNITED TELEPHONE COMPANY have been advised by eminent counsel that all forms of transmitter in which carbon is used in a free or powdered form, as for instance in the transmitters usually known as MOSELEY or HUNNINGS, and that all the so-called microphone transmitters, including those known as the CROSSLEY and the GOWER BELL, are infringements of Mr. Edison's patent of 30th July, 1877, No. 2909, as amended by disclaimer.

The United Telephone Company have acquired the patent rights granted to LOUIS JOHN CROSSLEY under the letters patent, dated 1st February, 1879, No. 412, and all rights to make, use, or sell the Crossley modification of the carbon transmitter, as now vested in the Company. Further, by arrangement with the CONSOLIDATED TELEPHONE CONSTRUCTION AND MAINTENANCE COMPANY, LIMITED (the owners of the Gower Bell Patents)

the UNITED TELEPHONE COMPANY have the sole right of supplying for use in this Country the Gower Bell modification of the carbon transmitter, constructed under the patents dated the 3rd October, 1878 (No. 3892), 25th January, 1879 (No. 315), 30th January, 1879 (No. 394), 24th February, 1880 (No. 814), 26th June, 1880 (No. 2610), and 30th December, 1880 (No. 5482), and no other persons or companies are entitled to supply the same for use in this Country.

No form of Magnetic Telephone, and no form of Transmitter in which Carbon or any other equivalent substance is employed whether known as EDISON'S, MOSELEY'S, HUNNINGS', CROSSLEY'S, GOWER'S, or by any other name, can be manufactured, sold, supplied, or used in this Country, except under LICENSE from the UNITED TELEPHONE COMPANY, LIMITED. PROCEEDINGS WILL BE TAKEN against persons infringing the Company's Patents and other rights as above set forth.

The public are CAUTIONED against using any of these instruments, except such as are obtained from the United Telephone Company, or their licensees, save and except any of 5000 transmitters made for her Majesty's Postmaster-General, and which bear special marks of identification, which are protected under the fiat of her Majesty's Attorney-General, dated the 4th day of June, 1881.

By order of the Board,
JAMES BRAND, Chairman.

6th July, 1881.

. . . . . .

THE UNITED TELEPHONE COMPANY (LIMITED) Hereby Give Public Notice, that Proceedings will be taken against the LONDON AND GLOBE TELEPHONE AND MAINTENANCE COMPANY (LIMITED), or against any other Person or Company, Manufacturing, Selling, Supplying, or Using TELEPHONE TRANSMITTERS or RECEIVERS, which are Infringements of the PATENT RIGHTS owned by the UNITED TELEPHONE COMPANY (LIMITED).

The UNITED TELEPHONE COMPANY (LIMITED) are advised that the Dolbear Transmitter, the Anders Microphone Transmitter, and the Hunnings Transmitter are all infringements of the Edison Patents, and instructions have already been given to the Company's solicitors to take legal proceedings, at the earliest possible moment, to restrain the Manufacture, Sale, Supply, and Use of these Instruments.

Lord M'Laren, in his decision in the case of The United Telephone Company (Limited) *v.* Maclean (which was an action to restrain the use of one of the so-called Microphone Transmitters) says: "It must be observed that Edison's Patent is not for a specific instrument, but for a combination in which the material element is an electric tension regulator, of which many forms

are given, all depending on a mode of action of great simplicity, and capable of being indefinitely varied. It may well be said that the instrument admits of as many variations as there are modes of bringing two surfaces into contact; but however unlike any particular variation may be to those which are described in the specification, yet if the contact is that of a semi-conductor of electricity, and is used in a telephone for the purpose of varying the resistance to the electric current in the line, I am of opinion that it is a form of Mr. Edison's invention, and that the words of the specification are broad enough to cover it."

The appeal against this decision was dismissed for want of prosecution.

Mr. Justice Fry, in the recent case of THE UNITED TELEPHONE COMPANY (LIMITED) and HARRISON, COX-WALKER AND CO. (the defence of which was conducted by the promoters of the London and Globe Telephone and Maintenance Company, Limited), says: "Is Hunnings' Transmitter an infringement of Edison's Transmitter? I have come to the conclusion that, like Edison's, it is the combination of a diaphragm vibrated by the voice, with a tension regulator consisting of a semi-conductive resilient and compressible substance, and that it is therefore within the scope of Edison's specification."

Mr. Justice Fry held that while the claim for the Phonograph remained in Mr. Edison's patent, the patent was not valid, and therefore refused to grant the injunction which would necessarily have followed from the decision above quoted.

On the 29th of July last the Attorney-General granted to THE UNITED TELEPHONE COMPANY (LIMITED) leave to disclaim the Phonograph, and this having been removed from the patent, no person can, according to Mr. Justice Fry's decision, manufacture, sell, supply, or use the Hunnings Transmitter except a limited number of specially identified instruments, which are protected by the Attorney-General's Fiat.

Mr. Justice Fry's decision has not been appealed against by the defendants so far as it relates to the Hunnings instrument.

By order of the Board,
JAMES BRAND, Chairman.

London, 8th August, 1882.

. . . . . .

It appears that the United Telephone Company caused to be printed, inside the cover of a list of telephone subscribers which they issued at this time, a statement similar to the first of the two announcements reproduced above.

The London and Globe Telephone and Maintenance Company took exception to paragraphs included in the statement in the

subscribers' list in question which were precisely similar to paragraphs two and four of the announcement dated July 6th, 1881, and they brought an action against the United Company to restrain them from continuing the publication of such printed statements, which, they contended, were in the nature of a libel upon their patents. Judgment in the case was given on Thursday, June 22nd, 1882, by Mr. Justice Fry, the presiding judge, who found for the plaintiffs. Mr. Justice Fry in his judgment said :—

"I determined in the action which was before me that Hunnings' patent could be manufactured, sold, supplied, and used in this country without a licence from the United Telephone Company. I, therefore, rightly or wrongly, determined the very opposite of the proposition which the defendants put forward. I am perfectly alive to the very great probability that my decision may be wrong. I know that it is at variance with the decision of an eminent judge in Scotland, but however great my sense of doubt may be at the ultimate decision of the case, I must bear in mind that I am a competent judge to decide a case and as long as my decision stands I am bound to act upon it. . . .

"It appears to me that I must restrain the defendants from setting out the paragraph which I have read and from making any other statement that Hunnings' transmitter cannot be manufactured, sold, supplied or used in this country except under the licence of the defendant company without reference to my decision; that is to say, I do not restrain them from saying that, provided they inform the public at the same time that I have decided the contrary. They are not to make the statement unless they qualify it by a reference to my decision, so long as that decision remains unreversed. There will be an injunction until the trial or further order."

Messrs. Harrison, Cox-Walker and Co., of Darlington, who were the respondents in the important and most interesting patent case which has been alluded to, exhibited considerable enterprise in the early days of the telephone in this country, and Mr. Edward Cox-Walker, who was the principal partner in the firm, has kindly supplied the author with interesting information reminiscent of his early telephone activities.

In his younger days, in 1852, Mr. Cox-Walker was associated with telegraphy, in the service of the old Electric Telegraph Company at York, where he became intimately acquainted

with Mr. W. H. (afterwards Sir William) Preece, who was at that time engineer for the Magnetic Telegraph Company.

Leaving the Electric Telegraph Company for a field which appeared to offer wider scope, he accepted an appointment as telegraph superintendent for the West Hartlepool Harbour and Railway Company, and, after a short residence in London and Liverpool, returned to York, where he became a manager for Messrs. Thomas Cook and Sons, opticians, of that city. While in that position, Mr. Cox-Walker, like many others, was attracted by the announcement of Graham Bell's discoveries and invention and began to experiment with the telephone; in 1878 he made his first telephone receivers based on a description which appeared in the *English Mechanic*.

He was closely acquainted with the Rev. Henry Hunnings, then a curate at Bolton Percy, near York, who discussed his ideas with him and showed him the crude transmitter he had devised and constructed. Numerous joint experiments were made and Mr. Cox-Walker collaborated with Mr. Hunnings in the production of the instrument which he ultimately patented (British Patent Specification 3647, September 16th, 1878) and which is described and illustrated in more detail elsewhere in this volume.

In 1880 Mr. Cox-Walker settled in Darlington and, adopting electrical engineering as a profession, entered into partnership with Mr. Harrison of that town with the object of establishing an electrical engineering business and specialising in telephones and electric tell-tales. He carried out numerous experiments with telephone receivers, which had for their object the production of an instrument of greater power than the Bell telephone. He devised, constructed and patented Duplex, Quadruplex, and Octuplex instruments, *i.e.*, magneto telephones with two, four, and eight pole pieces, coils and diaphragms concentrated into one ear-piece.

Mr. G. L. Anders, who has already been mentioned in connection with the Globe Company's telephone system, came from America, where he was engaged by the Bell Telephone Syndicate, to this country in 1880. During a visit which he paid to Darlington he heard of the Hunnings transmitter, and approached Mr. Cox-Walker in order to ascertain the merits of the instrument and have them practically demonstrated to

him. On putting it to the test, he expressed to Mr. Cox-Walker his amazement at its performance and declared that there was no instrument equal to it in this country or even in America; he suggested purchasing it outright for the Bell Telephone Company of America, and inquired from Mr. Cox-Walker what prospect there was of his acquiring the patent. Eventually he purchased it from Mr. Hunnings either on his own behalf, or as agent, for £1000.

In this way the Hunnings transmitter patent was purchased for Great Britain and came to be employed by the Globe Company, which was conducted mainly by Americans, Mr. G. L. Anders becoming electrician to the company, as previously mentioned, and Mr. Torrey secretary.

Mr. Cox-Walker states that the Hunnings transmitters of this early period, although admittedly not so powerful as the present day granular instruments, gave a much clearer and more faithful reproduction of the human voice than the transmitters of to-day.

Mr. Cox-Walker was soon engaged actively as a manufacturer of telephone and other electrical apparatus. Not only were his firm manufacturers for the Globe Company, but they undertook the design, manufacture, and supply of various types of telephones and small switchboards, and fitted them extensively in various parts of the County of Durham and elsewhere. They were the manufacturers for the Equitable Telephone Association, Ltd., of the Campbell Swinton telephone instruments referred to below, and were also manufacturers and vendors of other telephones, and apparatus of various types.

Messrs. Cox-Walker and Co. did not enter into the telephone exchange business, and when the famous patent case, particulars of which have been given, was settled, they largely relinquished their telephone business, and successfully sought less involved but more promising and remunerative branches in the realm of electric light and power engineering.

The business which Mr. Cox-Walker thus established, primarily as a telephone manufacturing concern, ranks to-day under the name of " Cox-Walkers, Ltd.," as one of the most thriving and important electrical manufacturing undertakings in the North of England.

Mr. Cox-Walker, though now 84 years of age, retains the position of governing director and chairman of the company,

although the management of the business is largely in the hands of his two sons.

In Fig. 26 appears an illustration reproduced from a photograph loaned by Mr. E. Cox-Walker of one of the several types of telephone instrument devised and manufactured by Messrs. Harrison, Cox-Walker and Co. The Hunnings transmitter is on the right hand side.

Two early forms of Hunnings' transmitter are illustrated in Fig. 27. The one on the right is the original form of Hunnings' granular carbon transmitter as made for practical purposes by Messrs. Harrison, Cox-Walker and Co.; the illustration has been prepared from a photograph of an instrument loaned to the author by Mr. E. Cox-Walker. The transmitter to the left in the illustration was one of those actually employed by the London and Globe Telephone and Maintenance Company and was loaned to the author for photographic purposes by the late Mr. J. W. Ullett, of Nottingham.

A further case of interest was brought by the United Telephone Company against the London and Globe Telephone and Maintenance Company and was heard on May 12th and 13th, 1884.

On May 27th, 1882, the Globe Company entered into a contract for the purchase of 800 Blake transmitters with an American agent, Mr. T. R. Welles, of Antwerp, and the transmitters, manufactured in America, came to England in March 1883 and were stored by the Globe Company. The United Telephone Company had secured an assignment of Blake's English patent and brought an action for infringement, claiming an injunction and surrender of the machines. The defendants dismantled the transmitters by removing the Blake elements and kept the separate parts stored in a warehouse. It was held by the court that possession of the transmitters by the defendants constituted an infringement of the United Company's rights and an injunction was granted, but the court declined to order the destruction or surrender of the infringing transmitters.

In Mr. J. E. Kingsbury's book on " The Telephone in Principle and Practice," of which mention has already been made, it is stated that on December 31st, 1881, there were fifteen telephone exchanges in London serving 1338 subscribers, and that call-rooms, or call-offices as they are now termed, had been established in different parts of London. For the benefit of those

who required the service of trusty messengers, the headquarters of the Corps of Commissionaires was connected with the exchanges. The Exchange Telegraph Company also placed their messengers at the service of telephone subscribers on payment of a moderate fee.

For some years after the telephone exchange service was inaugurated in London there was no regular night service, and exchanges were closed during holidays, the hours of service approximating to the hours of business generally adopted by the firms who formed the bulk of the subscribers.

All-night service was first introduced at the United Telephone Company's Heddon Street and Westminster Exchanges in February, 1885, and was intended originally chiefly for the use of members of Parliament.

It was not until about 1889 that the boy operators employed from the commencement of the exchange telephone service began to be replaced by girls.

An illustration of the United Telephone Company's "Eastern" Exchange, London, showing boy operators seated before the switchboard is given in Fig. 28.

In the course of a very few years from the inception of the telephone in London, when the business had become firmly established, the rapidly increasing number of overhead wires, and the introduction and employment of aërial cables erected across the principal thoroughfares of the City, began to excite public notice and comment. The unsightliness and alleged danger of the network of overhead wires above the streets and upon the roofs of the city became the subject of lengthy and frequent comment in the technical and general Press, and the outcry against these wires soon became universal. Various views and opinions were expressed as to the wisdom of permitting telephone companies to work their unfettered will above the public thoroughfares in such a manner, and suggestions were made that there should be control by some authoritative body. Questions were raised as to whether the public authorities already possessed powers which would enable them to enforce some measure of control over the companies, and compel them to obtain permission for the erection of wires over, along, or across public thoroughfares. Stories of accidents to pedestrians and others from falling wires were not lacking, and fears were

FIG. 26.—An early Telephone Instrument made by Harrison, Cox-Walker and Company, of Darlington.

(From a photograph loaned by Mr. E. Cox-Walker.)

FIG. 27.—Hunnings Transmitters: (*a*) Hunnings Transmitter used by the London and Globe Telephone and Maintenance Company. (*b*) The original form of Hunnings Transmitter manufactured by Harrison, Cox-Walker and Company, of Darlington.

(From a photograph of instruments loaned by the late Mr. J. W. Ullett and Mr. E. Cox-Walker.)

[To face page 76.

FIG. 28.—United Telephone Company's "Eastern" Exchange with boy operators.

(From a photograph loaned by the late Mr. J. W. Ullett.)

[*To face page 77.*

expressed that every street in the City would soon become covered with a dense cobweb or a huge gridiron of wires, and the wanton and insolent aggressiveness of the telephone companies in the matter was noted. An extended use of underground conductors was mentioned as a remedy.

Many other ideas were forthcoming, and suggestions were made for precautionary measures to be taken against accident, some of them, as usual when the uninitiated venture to enter the realm of engineering, more amusing than practical. One such was that the wires should be linked together at intervals by non-conducting material in order that mutual support might be afforded in case of the breakage of one wire.

In January 1884 representations were made by large property owners to the Local Government Board with the object of causing overhead wires to be placed under some form of regulation.

All this agitation and comment culminated in the action taken by the Board of Works for the Wandsworth District against the United Telephone Company in that the company had without the consent of the Board placed wires over, along, and across certain streets and highways for the purposes of telegraphic or telephonic communication, the same being alleged to be dangerous to persons using the streets. The Board contended that the company were subject to the provisions of the Telegraph Act of 1863, and that the Board, as owners of the soil, had absolute right to prevent the company from suspending wires over the road, on the principle that the air above the road was as much theirs as the road itself, and that the overhead wires were in fact dangerous to persons using the road and therefore a nuisance. They claimed an injunction against placing wires over streets under their control without their consent. The company denied that the wires were dangerous.

Mr. Justice Stephen, the presiding judge, gave his decision in favour of the Board, but withheld the injunction asked for on the ground that he did not think the wires caused any appreciable danger and that an appeal to a higher court was certain to be made.

The company entered an appeal, which came before the Master of the Rolls and Lords Justices Bowen and Fry in the Court of Appeal on June 12th and 13th, 1884. The Master of the Rolls

gave judgment to the effect that the wires were not placed upon property of the plaintiffs so as to enable an injunction to be granted on the ground of trespass, and Lord Justice Bowen gave a similar judgment in which Lord Justice Fry concurred.

This decision was of no small importance to the private telephone administrations and settled the question of the right of the telephone companies to erect and maintain wires over public thoroughfares. Had not the matter been settled in the company's favour there is no doubt that a great handicap would have been imposed upon their operations, and development of the telephone service consequently retarded.

In Chapter VII, which treats of the invention and practical development in this country of the multiple switchboard, allusion is made to the one devised by and constructed under the direction of Mr. F. B. O. Hawes for the United Telephone Company independently of the progress made in a similar direction in the United States. As the design of these switchboards was peculiar to London and was not in the direct line of development of the multiple switchboard, which became generally used throughout the country, it seems proper that Mr. Hawes' work should receive further mention in the present chapter.

The " Hawes " multiple switchboard was the direct outcome of the thoughtful study devoted by Mr. Hawes to the knotty problems which presented themselves for solution in the larger London exchanges at this time. One of the chief aims was to overcome the difficulties experienced by operators owing to the fact that only one point of access to each subscriber's line was available, and that there existed no effective and ready means for ascertaining whether a line terminated upon a remote position were engaged or not.

Experts in America had earlier experience and superior facilities for the development of their ideas than obtained in London under the *régime* of the United Telephone Company, and the Western Electric Company's patents precluded Mr. Hawes from developing further his ideas, and his two boards, one at Oxford Court brought into use on November 20th, 1883, and the other at Chancery Lane, a little later, were the only two boards of the kind ever constructed. Nevertheless, they are of considerable historic interest and produced, as they were, by Mr. Hawes, without knowledge of the earlier work done in America, they

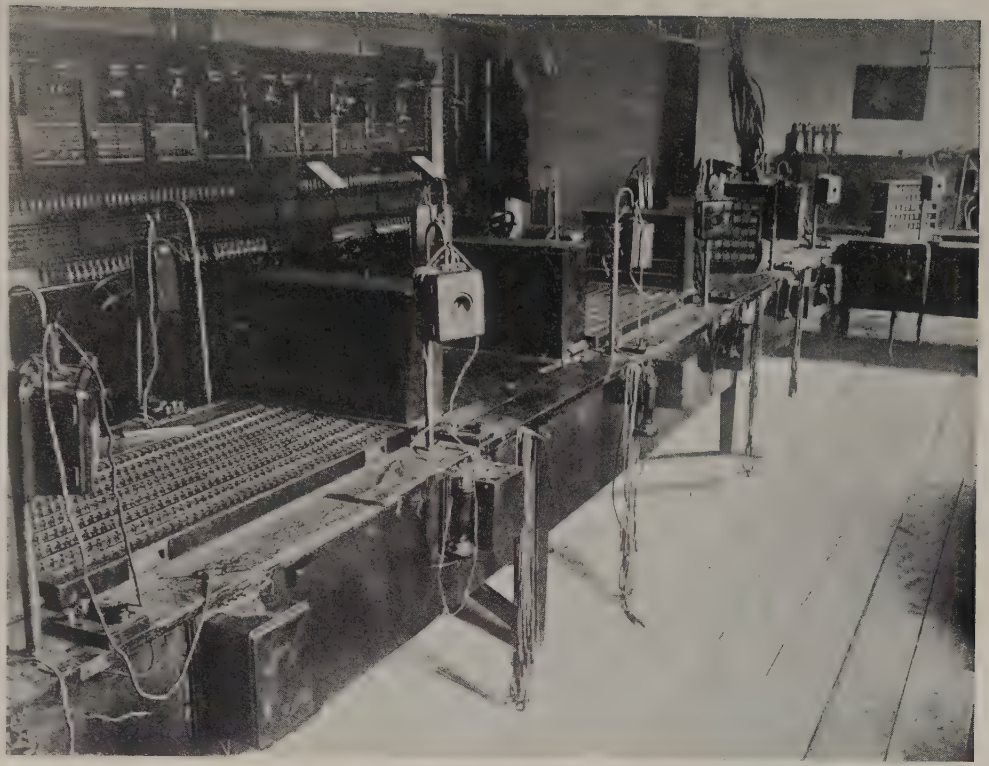

FIG. 29.—Hawes Multiple Switchboard, Chancery Lane Exchange, London.

(From a photograph loaned by the late Mr. J. W. Ullett.)

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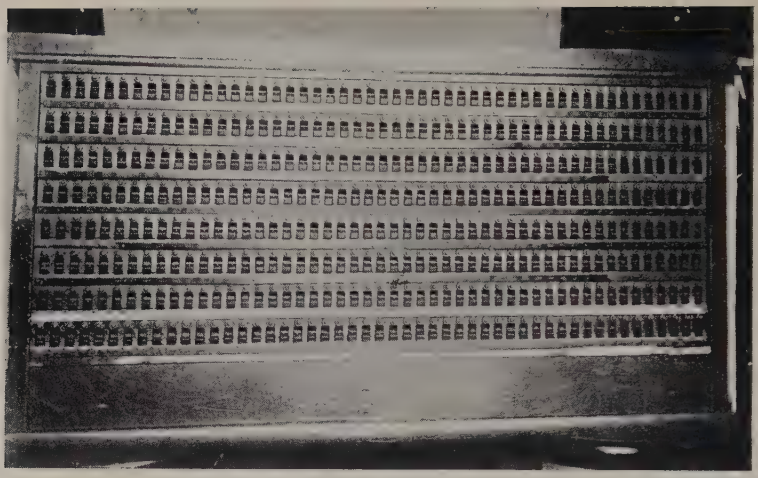

FIG. 30.—Hawes Multiple Switchboard; 400 line multiple section; upper side.

(From a photograph loaned by the late Mr. J. W. Ullett.)

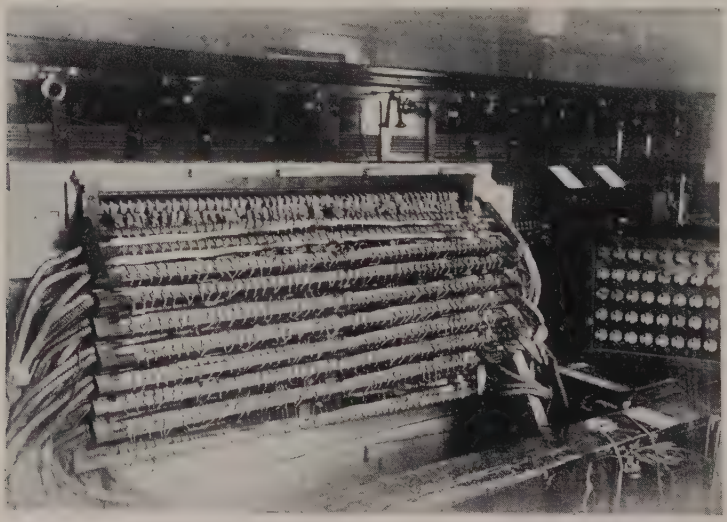

FIG. 31.—Hawes Multiple Switchboard; 400 line multiple section; under side.

(From a photograph loaned by the late Mr. J. W. Ullett.)

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show that a similar line of thought was followed independently in the two countries.

A photograph of the Hawes multiple switchboard at Chancery Lane, kindly loaned to the author by the late Mr. J. W. Ullett, was taken immediately before it was replaced by the modern Western Electric multiple equipment, which may be seen in the background of the same photograph; it is reproduced in Fig. 29; two further illustrations from photographs from the same source, one showing the upper and the other the under side of a multiple section of the same board, are shown in Figs. 30 and 31 respectively.

The multiple was arranged horizontally; each multiple section, or panel, accommodated 400 jacks with their associated engaged test contacts. The calling indicators of the subscribers to be answered at a given panel were accommodated at either side of that panel in the wooden cases, which may be seen in the illustration arranged transversely between the multiple sections.

The Hawes multiple switchboard may not inappropriately be described as the final development of the slipper-jack switchboard, inasmuch as the general features of the Clay-Hawes slipper-jack equipment were retained, with the application of multiple facilities.

The connections of the Hawes multiple are shown in Fig. 32; at (*a*) the wiring details of each jack element of a multiple section are given, and at (*b*) the complete multiple line connections of a subscriber's circuit. A series multiple was employed and the jacks were of the slipper type. The line spring of the jack carried, at its outer extremity, a small block of insulating material on which was supported a small plate of brass, and the equipment was completed by means of a test-stud and an earthed spring, so arranged that contact between the plate and spring was made and broken upon insertion or withdrawal of a plug.

On insertion of a plug into a jack, connection was made with the line and, simultaneously, the upward movement of the line spring thus caused lifted the brass plate into contact with the earthed spring. The relative plates and test-studs were multipled throughout the board, and were connected together as shown in the diagram (Fig. 32*b*); consequently insertion of a plug into any jack connected to earth all the multiple test-studs associated with that circuit.

The test-circuit, which was entirely independent of the speaking-circuit and of the operator's receiver, consisted of an earthed battery, a buzzer, and a flexible cord terminating in a test-thimble worn on the finger by the operator; when the test-thimble was brought into contact with the test-stud of a line which was engaged at any other position the test-battery circuit

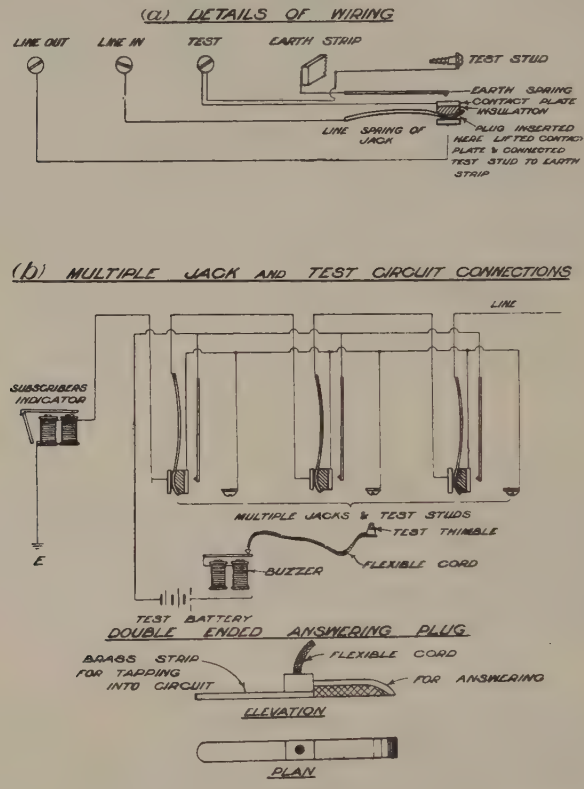

FIG. 32.—Hawes Multiple Switchboard, electrical connections.

was completed, and the fact that the line was engaged was announced by operation of the buzzer.

The connecting cords were single-way flexible cords provided at each end with flat plugs for insertion into the jacks. There were no clearing indicators, and the operator ascertained whether or not conversation was in progress by tapping the circuit. Although subscribers in those early days were expected to give a clearing signal, they generally failed to do so and therefore

clearing indicators were at that time considered to be of little use. There were therefore no automatic clearing signals.

There were no local jacks, answering being done at the multiple, that is, the panel. The answering plug was formed as indicated roughly in the lower portion of Fig. 32. It was a double-ended plug with either end connected to the single-way flexible cord attached to the operator's instrument. One end of the plug, used for answering, consisted of a strip of brass, mounted on a strip of insulating material. The other end was a straight prong of brass, and could be inserted in a jack above the plug of a connecting cord, in order that a connection might be tapped without breaking the circuit.

The three photographs which appear in Figs. 29, 30, and 31, and the information from which Fig. 32 has been prepared, were kindly supplied by the late Mr. J. W. Ullett, and Fig. 32 has been confirmed by Mr. Hawes himself.

The early technical development and application of the multiple switchboard in this country is dealt with in Chapter VII.

As stated above, the first switchboards of the multiple type in the United Kingdom were the two devised by Mr. Hawes for the United Telephone Company's exchanges at Chancery Lane and Oxford Court, London, but the first switchboards of the Western Electric Company's upright multiple type, which were eventually employed universally, were installed at the provincial centres of Liverpool, Glasgow, and Sunderland. London was therefore behind in this respect, and it was not until 1888, four years after the introduction of the first upright multiple switchboard at Liverpool, that a similar board replaced the Edison switchboard at 11 Queen Victoria Street, which, with frequent modification and extension, had given service for some years. This switchboard was the first of a series of five similar Western Electric multiple boards, embodying the latest improvements, to be fitted in London after their superiority over other available means of telephone switching had been proved by installations in the provinces. An illustration of the new switchboard at 11 Queen Victoria Street, from the late Mr. Ullett's collection, appears in Fig. 33. Each section comprised three operators' positions—each equipped with ten pairs of plugs and cords and their associated keys, and ring-off indicators—subscribers' indicators to the number of 120, and a five-panel multiple having a capacity

for 1500. The operators' instruments consisted of Blake transmitters in wooden cases fitted with single-pole hand receivers, supported from above by adjustable brackets.

The other four London exchanges, similarly equipped with Western Electric multiple switchboards, and which quickly followed Queen Victoria Street, were Cornhill, Chancery Lane, Smithfield (67 Cow Cross Street, E.C.), and Westminster. They were brought into service in the order named, and with one or two minor differences were precisely similar to the board at Queen Victoria Street.

The new switchboard at Chancery Lane was erected immediately behind the Hawes multiple board which it displaced and is discernible in the background in Fig. 29, illustrating the Hawes board. Blake transmitters in nickel-plated cases, made specially for switchboard work, were employed, and their height was adjustable in a manner similar to that adopted for the Westminster board, to be referred to immediately. Transmitters of this pattern, one of them illustrated in Fig. 161 at *b*, were generally employed throughout the country at this time, and continued in use until the universal adoption of head-gear receivers and breast-plate transmitters.

Fig. 34 shows the new switchboard installed at No. 6 Victoria Street, Westminster, which succeeded the Clay-Hawes slipper-jack equipment previously mentioned and illustrated in Fig. 14.

This switchboard, the last of the five to be completed, was brought into use on November 24th, 1888; the photograph, which again is from Mr. Ullett's collection, was taken shortly prior to that date.

The details of the equipment of an operator's position are well shown in Fig. 35. It will be observed that each of the Blake transmitters was contained in a case which did not offer so much obstruction to the operator's view of and access to the jacks as the ordinary wooden-cased instrument, and that they were suspended from above by cords carried over pulleys, with counter balances so arranged as to facilitate adjustment to any reasonable height, whether the operator were standing or sitting; also that the single-pole receivers were mounted separately.

The switchboard in Fig. 28 is of special interest. It represents the exchange known as Eastern, which replaced the slipper-jack board accommodated in an attic of the Eastern Hotel, Limehouse.

FIG. 33.—First Western Electric Upright Multiple Switchboard in London, 11 Queen Victoria Street, E.C.

(From a photograph loaned by the late Mr. J. W. Ullett.)

FIG. 34.—Western Electric Multiple Switchboard, 6 Victoria Street, Westminster.

(From a photograph loaned by the late Mr. J. W. Ullett.)

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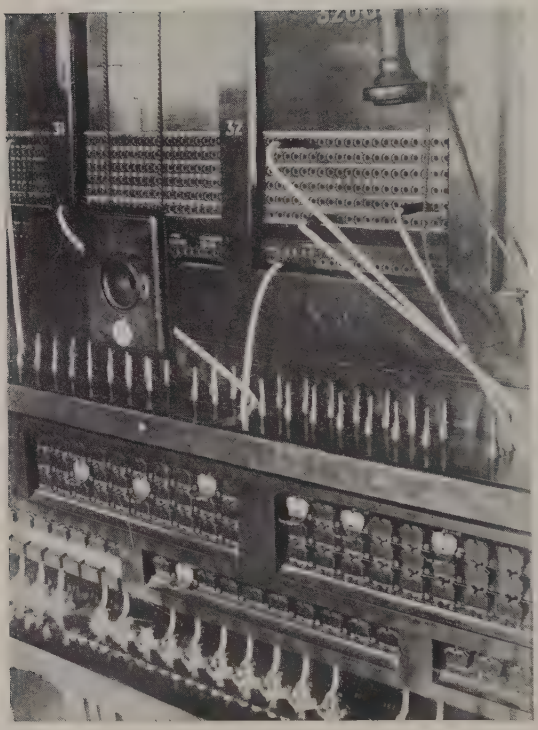

FIG. 35.—Western Electric Multiple Switchboard, Westminster. Operator's position.

(From a photograph loaned by the late Mr. J. W. Ullett.)

[*To face page* 83.

In this illustration, the boys, then customarily employed as operators, appear in their positions at the switchboard. This equipment was constructed out of that recovered from the London and Globe Telephone and Maintenance Company's exchange at the Wool Exchange, after its acquirement and subsequent demolition by the United Company.

When the necessity arose for substituting a modern multiple switchboard for the old slipper-jack exchange at 36 Coleman Street, opportunity was taken to instal the new equipment in premises affording more adequate accommodation, and the premises acquired from the London and Globe Telephone and Maintenance Co. at the Wool Exchange in Basinghall Street were adopted as being conveniently situated and otherwise suitable. Fig. 36 shows the Western Electric Company's multiple switchboard erected there about twelve months after the Westminster switchboard, and operated under the designation " Wool Exchange."

It will be observed that the equipment did not materially differ from the other Western Electric switchboards which have been mentioned, but the sections were of larger multiple capacity. Eventually the " Wool Exchange " was transferred to London Wall and became known by that name. Thus the present London Wall Exchange, which at one time accommodated nearly 9000 subscribers, had its origin at 36 Coleman Street, and is to-day the representative of the first telephone exchange opened in London.

The reader will no doubt have observed that the number of exchanges established in the early days of the telephone in London was large in proportion to the number of subscribers. Consequently inter-exchange communication was a prominent and important feature in the Metropolis and incidentally has so continued up to the present time. In order to facilitate manipulation of inter-exchange traffic, in 1883 a central trunk exchange was established by the United Telephone Company at Oxford Court, Cannon Street, to which trunk lines—or as they would now be termed junction lines—were connected from each of the local exchanges in addition to those which connected them directly.

The Oxford Court premises were taken soon after the amalgamation of the Bell and Edison interests, and the first trunk

switchboard established there consisted of a flat multiple switchboard constructed to the design and under the superintendence of Mr. F. B. O. Hawes. It was brought into service on November 20th, 1883, and consisted of two multiple sections, with 100 lines terminated on each, together with call wires communicating with certain of the local exchanges. The Hawes board at Oxford Court, already mentioned in this chapter and referred to in Chapter VII, was eventually replaced, in about 1889, by the multiple switchboard illustrated in Fig. 37 from a photograph included in the late Mr. Ullett's collection. This switchboard consisted of six sections, each equipped with 300 jacks of specially substantial type, and constructed with an independent test-circuit. The engaged test was applied by means of a test-thimble worn by the operator on a finger of one hand, and the audible test signal given by a watch receiver as seen in the illustration hanging immediately behind the operator's fixed transmitter. Junctions between Oxford Court and the smaller and usually more distant exchanges were terminated on indicators and jacks accommodated on a section of the board specially fitted for them, and were worked as subscribers' lines. When the group of junctions was large enough call-wire working was practised, with the incoming lines terminated on plugs and cords when the number of junction lines exceeded six or eight. This switchboard was eventually extended by the addition of three sections, one of them equipped with self-restoring indicators for junctions to the smaller exchanges and for long distance trunks.

The United Telephone Company's policy of working the Metropolitan telephone service with such a large number of exchanges in proportion to the total number of subscribers was criticised by *The Electrician* in 1888 and contrasted with that of the National Telephone Company in Glasgow, where 1570 subscribers' lines were accommodated on six exchanges, and more particularly with that of the Lancashire and Cheshire Company, who served the 1350 subscribers in Manchester from one central exchange. In London, at the same time, there were no less than twenty-three exchanges, in addition to the trunk exchange, accommodating approximately 4800 subscribers' lines, and on April 27th, 1888, the trunk circuits entering the Oxford Court Exchange numbered 270.

FIG. 36.—Western Electric Multiple Switchboard, Wool Exchange, Basinghall Street, London, E.C.

(From a photograph loaned by the late Mr. J. W. Ullett.)

FIG. 37.—The United Telephone Company's Trunk Exchange, Oxford Court, Cannon Street, London, E.C., 1889.

(From a photograph loaned by the late Mr. J. W. Ullett.)

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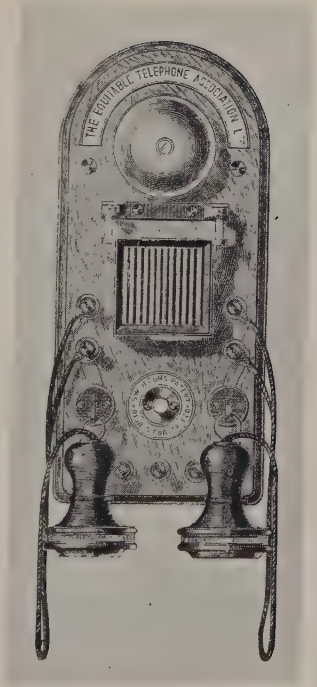

FIG. 39.—Mr. Campbell Swinton's telephone instrument made by Harrison, Cox-Walker and Company for the Equitable Telephone Association, Ltd.

(From a trade circular lent by Mr. E. Cox-Walker.)

FIG. 40.—The United Telephone Company's Head Offices, Oxford Court, Cannon Street, London, E.C., with "Ironclad" derrick on roof.

(From a photograph loaned by the late Mr. J. W. Ullett.)

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In 1885 the New Telephone Co., Ltd., with offices at 4 Great Winchester Street, London, E.C., was floated for the purpose of exploiting an invention made and patented by Professor Silvanus P. Thompson, in the form of what was known as the valve transmitter. Telephone instruments of different design were manufactured, and were disposed of to the public, including certain telephone companies, during a period of about four years; an advertisement issued by the firm announced that a formal guarantee would be given against any claims which might be made by trade rivals for alleged infringement.

The Valve Telephone was the subject of no less than three patent specifications, viz.: No. 3803 of August 9th, 1882, No. 8524 of June 3rd, 1884, and No. 3037 of March 7th, 1885, in which several forms of the device are described and illustrated. Associated with the invention are the names of Silvanus Phillips Thompson, of University College, Bristol, doctor of science and professor of experimental physics, and Philip Jolin, of 2 Elmdale Road, Redland, Bristol, engineer.

Perhaps the chief feature of the claim was the absence of a diaphragm, which, it was alleged, absorbed and reflected the sound waves, and produced secondary disturbing vibrations, with the result that articulation was impaired.

The term " valve " used in relation to telephony is, in these days of the thermionic valve, apt to be misleading, and it should therefore be explained that the term merely had reference to the fact that the working parts of the instrument intended to act as a transmitter were constructed in the form of an ordinary mechanical ball-valve, as used, for example, in a simple form of hydraulic pump, one of the electrodes being analogous to the valve-seat and the other to the ball. The sound-waves to be transmitted were directed upwards through a suitably arranged tube upon the ball, in such a manner that they tended to lift it from its seat and in this way the intimacy of the electrical contact between the ball and its seating was varied.

Fig. 38 has been constructed from information contained in Specification No. 8524 and no doubt will make clear the construction of the device. The drawing illustrates the form in which the inventors claimed to have secured the best results; in this design the resistance of the circuit was varied by points of contact formed by supporting the loose sphere, or ball of

conducting material, upon three pins arranged tripod fashion. At the points of contact with the ball, the pins were preferably tipped with gold, platinum, iridium, or other non-fusible metal or conducting material. The specification stated that in the construction of the contact pieces the use of phosphor-bronze, silicium-bronze, selenium-bronze, tellurium-bronze, and sulphur-bronze gave good results. Two pins were connected together to

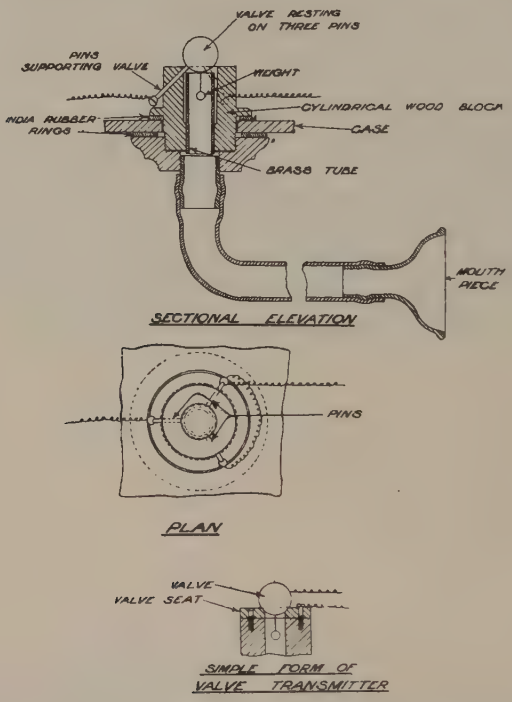

FIG. 38.—The Valve Telephone Transmitter patented by Professor S. P. Thompson and Philip Jolin, employed by the New Telephone Co., Ltd.

form one electrode, and another was formed by a third pin, the supported ball of conducting material maintaining connection between the two.

The specifications, with their associated drawings, are an indication of the large amount of care and attention which appears to have been spent by the inventors upon the device.

On April 12th, 1889, a case was brought by the United Telephone Company against the New Telephone Company when the

Attorney-General, who had been instructed to move for an injunction, appeared, on behalf of the plaintiff company before Mr. Justice North, sitting in the Chancery Division. The Attorney-General stated that the defendant company had submitted to an order for a perpetual injunction restraining them from using a transmitter alleged to be an infringement of the Edison patent. The plaintiff company had ascertained that the receiver was an infringement of Bell's patent, which was also vested in the plaintiff company, and defendants had now agreed that the writ should be amended so as to include in the injunction both transmitter and receiver. Defendants had agreed to deliver up all the infringing instruments, and the plaintiff company therefore agreed to waive all claim for damages against the defendants. The plaintiff company did not desire to press hardly upon persons who had purchased infringing instruments, but they wished it to be known that they were restraining all persons from using them.

The defendant company, as they were bound to do, had delivered up the names of the purchasers and, if they delivered up infringing instruments within one month, the plaintiff company would not press for damages.

The necessity for delivering up all the instruments in use at the time placed the users of such instruments in a somewhat peculiar position, and they were left to take what action they thought fit. Several firms were involved in possession of the infringing instruments, and consideration was given, and, it is believed, counsel's opinion taken, as to the advisability of taking action against the directors of the New Telephone Company for compensation for losses sustained by their default in not carrying out their undertakings, but the matter does not appear to have progressed very much further.

Some 2000 instruments were surrendered, and the United Telephone Company adopted the policy of waiving proceedings against purchasers and users, on their giving up the offending instruments. In many cases telephone companies, acting in co-operation with the United Company, supplied licensed instruments in their place.

Steps were at once taken to wind up the affairs of the New Telephone Company, and the Court made a winding up order against the company in June 1889.

The Equitable Telephone Association, Ltd., was incorporated on December 15th, 1886, with offices at 75 Queen Victoria Street, London, E.C., under licence from H.M. Postmaster-General, for the purpose of exploiting the Swinton Patent Electric Telephones. Fig. 39 is a reproduction of an illustration which appeared, in a trade circular issued by the firm, of one of the complete instruments made by Messrs. Harrison, Cox-Walker & Co., of Darlington.

The firm advertised these instruments for sale in preference to hire, in view of the refusal of the holders of the Edison and Bell patents to sell instruments outright and of their system of almost prohibitive rentals.

The company indemnified all purchasers and users against any claim for alleged infringement, and stated their willingness to give a formal guarantee under seal to that effect, in view of the opinion of eminent counsel that their instruments were entirely free and distinct from the Edison and Bell patents. A complete set of telephone instruments, as illustrated, for two stations, comprising two transmitters and four receivers with call bells and switching apparatus, was priced £12.

An interesting circular issued by the Equitable Company well illustrates the method by which it was contended that the Edison and Bell patents had been avoided and reads as follows :—

FREEDOM OF THE SWINTON TELEPHONE INSTRUMENTS

From the Present Monopoly

As is well known, the present TELEPHONE MONOPOLY is due to the "Edison" and "Bell" patents.

THE EDISON PATENT, which is for the transmitting portion of the apparatus, originally contained 30 claims; but 29 of these have been specifically disclaimed, leaving the solitary claim for: "The combination with a diaphragm or tympanum of electric tension regulators, substantially as described."

The specification expressly states that nothing further than this combination is claimed.

The following extract from Lord M'Laren's judgment in the case of the United Telephone Company versus Maclean is important :—

"Now as Edison's patent is for a tension regulator in combination with a diaphragm or tympanum, it follows that the interdict sought would not apply to the use of the respondent's carbon regulator without a tympanum."

The Swinton Transmitter consists of a lead frame supporting pencil microphonic regulators of special design, which are sufficiently sensitive to be actuated directly by the air waves.

A special mounting prevents any vibrations of the case or support of the instrument from reaching the regulators, which are worked entirely by the aforesaid direct impact of the air waves, without the intervention of any diaphragm or tympanum, Edison's Combination being thus altogether absent.

The Bell Patent, which originally claimed all manner of telephone receivers, has now been modified by a disclaimer; in this occurs the following important clause, which is expressly stated to limit all the claims :—

"And it is to be noted that no claim is made to the use of telephonic apparatus wherein a membrane like gold-beater's skin is used in combination with an electro-magnet, excited by a battery which is arranged in the main circuit or line wire."

The Swinton Receiver is a perfected form of this membrane electro-magnet instrument, specifically disclaimed from the Bell Patent. A specially prepared membrane is employed in combination with an electro-magneto excited by a battery in the line wire.

The Equitable Telephone Association, Limited,
75 Queen Victoria Street,
London, E.C.

The transmitter patents of Mr. A. A. Campbell-Swinton were included in British Patent Specifications Nos. 3551 of February 19th, 1884; 16954 of December 27th, 1884, and 8122 of July 4th, 1885. His receiver, as well as the electrical arrangement of the speaking circuit of the complete instrument, was covered by Specifications Nos. 7109 of May 27th, 1886, and 16458 of November 30th, 1887.

A licence was granted to the Equitable Telephone Association, Ltd., by the Postmaster-General for the United Kingdom in September 1887.

The operations of the Association and the manufacturers of their instruments, Messrs. Harrison, Cox-Walker and Co., of Darlington, were closely watched by the United Telephone Company, who eventually took legal action to stop the manufacture and use of the Stanhope instruments, which, they contended, were an infringement of their patents. A writ was issued on behalf of the United Company on March 9th, 1888, and in the same month they obtained an interim injunction from Mr. Justice Chitty in the Court of Chancery restraining the

Association from making and selling instruments pending trial of the action.

The Equitable Association announced their intention of pressing the matter to as early a trial of the case as was practicable, but nothing further appears to have transpired.

The circumstances which led to the amalgamation of the United Telephone Co., Ltd., with the National and Lancashire companies are related briefly in Chapter IX. The name of the United Telephone Company disappeared on May 1st, 1889, when the National Telephone Co., Ltd., took over the administration of the London telephone service, together with the United Company's other responsibilities.

The financial results of the working of the United Company, during its nine years of activity, are indicated in the statement in Table I, extracted from the report of the company's directors for the year ending April 30th, 1889.

The equivalent purchase price paid by the National Telephone Company for the United Company's undertaking was £957,144 15*s.* 2*d.*, with which amount capital account was debited in the financial statement issued by the National Company for the year ended April 30th, 1890.

A photograph of the United Telephone Company's head offices at Oxford Court, Cannon Street, London, E.C., with the " Ironclad " derrick upon the roof is reproduced in Fig. 40.

CHAPTER IV

INTRODUCTION OF TELEPHONY INTO THE PROVINCES, 1879–1886

The Parent and United Telephone Companies and Others

So far consideration has only been given to the introduction of commercial telephony into the Metropolis.

It was fitting that the first scenes which opened the telephone era and introduced the telephone into this country should be enacted in the capital city of the United Kingdom. London was the main centre of telephone activity from the very first and has so remained until the present day.

But matters telephonic had not meanwhile been neglected in the Provinces.

Bell's receiver and Hughes' microphone were instruments of simple design, being free from complex parts, and they lent themselves readily to a simple form of construction and to experiment. Consequently there were few electricians and amateurs who did not become practically interested in the invention and constructed for themselves in some form or other magneto telephones and carbon microphones, after the respective ideas and designs of Bell and Hughes. Numerous engineers, electricians and others in different parts of the country, recognising the commercial possibilities which it presented, took upon themselves the exploitation of the telephone as a financial project. Private telephone businesses were started for the purpose of providing telephonic communication and in some cases exchange service was established.

In due course the Telephone Co., Ltd., and the Edison Telephone Company extended their operations from London to the Provinces, and opened one or two exchanges in towns which gave promise of supplying a field for profitable business.

The information included in this chapter has been collected from various widely scattered sources available to the author, but, owing to the popularity which the telephone enjoyed in its

infancy, the large number of individuals who interested themselves in it, the lapse of time, and absence of records, it is not practicable to ensure that all those who were amongst the prime movers in the establishment of telephone service in this country receive the mention merited. It is, however, hoped that mention of none of those of first importance is omitted.

The telephone was first introduced into Manchester by Mr. Charles Moseley, of Messrs. David Moseley and Sons, india-rubber manufacturers. With many others, Mr. Charles Moseley became keenly interested in the telephone and its possibilities soon after the announcement of its invention. In November 1877 Mr. W. F. Bottomley, who afterwards went to Dublin as engineer to the Telephone Company of Ireland, where he died in 1891, became associated with the firm as engineer, and a business for the provision of private wire telephone services was built up. In 1879, Messrs. Moseley and Sons acquired a patent for a granular carbon transmitter (British Patent Specification No. 2497, June 21st, 1879) invented by Mr. Alexander Marr, who joined the firm as head of the construction department. Telephone apparatus of various descriptions was manufactured and supplied to the Post Office, certain railway companies, and private firms.

The Marr transmitter, a modification of the original Hunnings instrument, was really the first granular transmitter to be used successfully in actual practice. It is illustrated in Figs. 160 and 161. It was the first in which electrodes of solid carbon were employed in place of the platinum diaphragm of Hunnings. The dimensions of the electrodes were $\frac{5}{8} \times \frac{5}{8} \times \frac{1}{16}$ inch. They were mounted at a separating distance of $\frac{1}{16}$ inch, one at the centre of the diaphragm of thin pine wood $2\frac{1}{2}$ inches in diameter and the other in the back of the case.

At a later date Mr. Marr produced another granular transmitter specially designed for the transmission of opera music in Manchester. It was known as Marr's inertia transmitter, and consisted essentially of a heavy square cell of brass provided with carbon electrodes, in which the carbon granules were contained, the cell being attached to an iron diaphragm. This transmitter, illustrated in Figs. 160 and 161, gave excellent results, not only for the particular purpose for which it was made, but also for long distance working. It was used successfully for transmission

of music from Manchester theatres in 1880–1881. A further transmitter, designed by Mr. Marr, and patented by Mr. Moseley, is described in British Patent Specification (Provisional) No. 2451 of May 24th, 1882.

Transmitters of the granular carbon type, manufactured by Messrs. Moseley, were at one time supplied to and employed by the British Post Office, prior to the introduction of the Deckert.

A complete telephone instrument designed by Mr. Marr, and manufactured by Messrs. Moseley, is illustrated in Fig. 41. It consisted of a Marr transmitter and a Gower receiver with double ear tubes and was supplied for use in signal cabins to the London and North-Western, the Midland, the Manchester, Sheffield, and Lincolnshire (afterwards Great Central) and the Lancashire and Yorkshire railway companies.

Mr. Charles Moseley was associated with Messrs. W. F. Bottomley and W. E. Hayes in the patent No. 2690 of July 1st, 1880, which covered the erection of telephone lines on the "twist" or "rotated" system. These gentlemen were engaged for some months previously in conducting experiments which culminated in the patent referred to, but it was never enforced owing to the subsequent discovery that Professor Hughes had described the principle of the invention to the Physical Society some time before the date of the patent. As is well known, the twist system was adopted universally in this country by various telephone administrations and by the Post Office.

Preparations were made by Messrs. D. Moseley and Sons for the establishment of exchange service at 2 and 4 New Brown Street, Manchester, and in some adjacent towns, and in August 1881 they advertised that fact in the *Manchester Guardian*. The rates to be charged were £12 per annum for service to subscribers within a radius of one mile, and £17 within two miles of the exchange. The advertisement stated that arrangements had been entered into with the Postal Authorities for the provision of telephonic communication between Manchester and Warrington, Rochdale, Oldham, Stockport, Ashton-under-Lyne, Bury, Radcliffe, and Bolton. The Gower Bell loud-speaking telephone was to be used, and wires were to be erected on Moseley's patented system, which, it was claimed, entirely obviated the great difficulties and interruptions then experienced from induction and other influences. A switchboard of the Blakey and Emmott

type for 25 subscribers was ordered, but the scheme never reached fruition and the exchange was never opened owing, it is understood, to a difficulty which arose in connection with the acquisition of the necessary licence.

In August 1879 the Lancashire Telephonic Exchange, Ltd., was registered, with offices in the Royal Exchange, Manchester. This company was licenced to operate the patents vested in the Telephone Co., Ltd., of 36 Coleman Street, London. Messrs. J. D. Tracy and J. G. Lorrain were the managers. Mr. Tracy was previously instrumental in founding some of the important exchanges in America. Mr. G. R. Dewhurst, of Manchester, was a director of the company. An inclusive charge of £20 per annum was made for an exchange line. This company opened the first exchange to be brought into operation in Manchester, some time during the latter half of the year 1879. The switchboard was precisely similar to the one installed at 36 Coleman Street, London, E.C., described in Chapter II.

In September 1879 representatives of the Edison Telephone Co. of London, Ltd., appeared in Manchester, advertised in the local newspapers, and gave a practical demonstration of the utility of the telephone by means of Edison's telephone instruments, similar to those used in London and already described. Instruments were fitted at either end of an existing telegraph wire, between the warehouse of Messrs. E. Potter and Co., calico printers, Charlotte Street, Manchester, and Messrs. Potter's works at Dinting, 13 miles away. Mr. A. T. Turney, who later became intimately associated with the Western Electric Co. in cable manufacture, was one of Edison's representatives who visited the provinces at this time, gave demonstrations of the use of the Edison instrument, and opened exchanges on behalf of the Edison Company; one of the exchanges opened by Mr. Turney was at No. 8 Commercial Buildings, 15 Cross Street, Manchester. The advertised inclusive charge for exchange service was £12 per annum.

The ultimate absorption by the Lancashire and Cheshire Telephonic Exchange Co., Ltd., of the Edison Telephone Co. and Messrs. David Moseley and Sons is referred to in Chapter VI.

Telephone business was opened in Liverpool in August 1879, when a company was formed under the title The Lancashire Telephonic Exchange, Ltd., for the purpose of carrying on

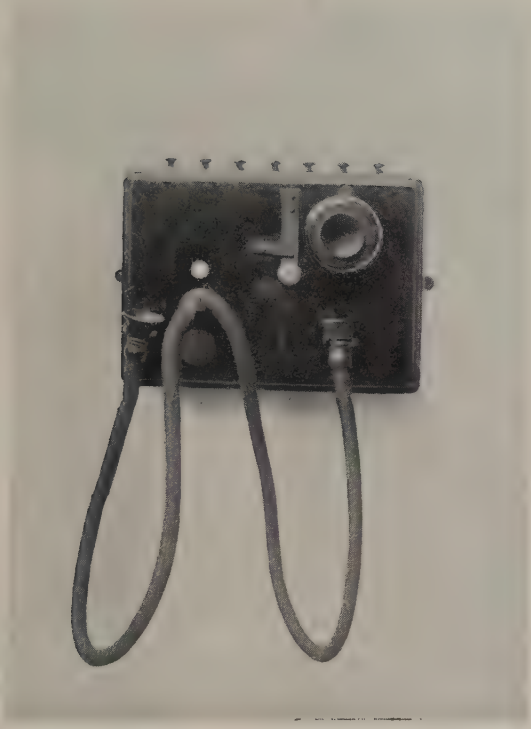

FIG. 41.—Telephone Instrument with Marr transmitter and Gower receiver, manufactured by Moseley and Sons, of Manchester, 1880.

(From a photograph supplied by Mr. F. W. Best.)

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FIG. 42.—Liverpool Central Telephone Exchange, 1884.
(From a photograph supplied by Mr. T. Cornfoot.)

[*To face page* 95.

telephone business in that city and the county of Lancashire. Mr. R. F. Claxton, ultimately to become superintendent for the National Telephone Company's North-West Province, was manager for the district. Three hundred firms in Liverpool were induced to become subscribers to the exchange system for a period of one year, at a rental of £20 per annum.

An exchange was in operation in Liverpool by October 1879 and was fitted and brought into use under the direction of Mr. J. G. Lorrain. The switchboard was similar to the one he had previously erected in Manchester. It had a fitted capacity for 75 lines. Early in 1880 this switchboard was altered in order that through connections *via* the operating table might be avoided. The tables were retained and utilised as single operating instruments. Each connection was afterwards effected by means of a simple connecting cord with plugs at each end, the two plugs being inserted, one in the calling and the other in the wanted subscriber's slipper after the operator had secured the attention of the subscriber called. The capacity to deal with calls was, by this alteration, considerably increased, the number of conversations which could be maintained at one time being governed by the number of connecting cords available. Switchboards of this type continued in use in Liverpool until 1884, at which date the exchange had grown to the extent indicated by Fig. 42. In 1882 there were approximately 450 subscribers connected to the system.

There are to-day many branches of electrical engineering, but originally the work of the electrical engineer embraced everything electrical. The telephone was in its infancy at the same time as other branches of electrical science, notably electric lighting. These two services, telephony and electric lighting, began to develop together and, being very similar in their requirements, it is not surprising that in certain parts of the provinces they were worked conjointly by one and the same firm. There were several examples of the associated early development of telephony and electric lighting. As implied by the title, the Sheffield Telephone Exchange and Electric Light Co. is one obvious example, and Messrs. M. Volk and Co., of Brighton, is another referred to elsewhere in this chapter. In Glasgow also, the telephone and the electric light were first introduced and developed by a firm which, through the efforts of its enterprising

head, gained for itself an early reputation in the realm of electrical engineering. During the period under review, Mr. David Graham was the sole partner of the firm of D. and G. Graham, Clarence Works, Sauchiehall Street, Glasgow, a firm founded by his father, and he was the pioneer of both telephony and incandescent electric lighting in the largest city and centre of industry in Scotland.

Mr. David Graham has kindly supplied the author with interesting particulars anent the introduction of the telephone and of electric lighting by means of the incandescent lamp into Glasgow, and to him he is indebted for the following information.

Mr. Graham states that the first telephone exchange in Glasgow was established at 140 Douglas Street, prior to the month of March 1879, under the designation of "The Glasgow Medical Telephone Exchange." As implied by the name, the exchange service was first instituted for the exclusive use of doctors, chemists, and others with allied interests, including hospitals and infirmaries. Night and Sunday service was rendered from the outset and facilities were thus afforded for calling up a doctor at any hour of the day or night. To this "Medical" Exchange was soon added another termed the "Legal," for members of the legal profession, to be quickly followed by the "Stockbrokers" and the "Commercial" Telephone exchanges. Independent switching facilities were provided for each of these four groups of subscribers of different professions, but ultimately means were afforded for intercommunication between the four groups. In this way commenced the historic "Douglas" exchange of Glasgow.

The success of the telephone for purposes of intercommunication thus being amply demonstrated, Mr. Graham proceeded in the following year (1880) to open another exchange at 31 St. Vincent Place, Glasgow, worked in conjunction with "Douglas."

Thus in Glasgow early policy was to classify the respective professions or businesses as described, a policy which, no doubt, did much to establish quickly the telephone as a going concern in that city.

Subscribers' agreements contracted for a period of not less than five years, a stipulation exacted for the firm's protection, and to induce new members of the professions indicated to subscribe to the system already established rather than to a competitive system which might be set in operation.

Supplies of telephone instruments were first obtained from the Bell Telephone Syndicate (the Telephone Co., Ltd.), but this company secured premises in Queen Street, Glasgow, and in order to support the opposition which they created by the establishment of a competitive exchange at that address, they declined to supply Mr. Graham with further instruments and, as a consequence, the Gower Bell loud-speaking telephone was adopted, and continued to be used so long as the telephone business remained in the hands of Messrs. D. and G. Graham. The switching arrangements adopted comprised switchboards with flexible cords and plug connections, associated with ordinary drop indicators for signalling purposes. Larger boards of this design were manufactured to the order of Mr. Graham by Mr. Edward J. Paterson, then of 76 Little Britain, London, E.C.

The necessary lines, of single wire with earth return, were all overhead, No. 11 B.W.G., galvanised iron wire, manufactured to the Post Office specification being first employed; phosphor-bronze wire was soon introduced in place of iron, owing to its superior durability and tensile strength. Wrought iron tubular poles were employed at an early date for supporting the necessary wires.

In order to secure retention of wayleave facilities, Mr. Graham bound himself to maintain in a reasonable state of repair the roofs of all the buildings he made use of, on the understanding that no competitor was to be allowed access to them, a policy which had the effect of seriously handicapping subsequent competitors.

The original annual subscription to Messrs. Graham's system was £12, subsequently increased to £15 per annum in order to cover the royalty charges which were imposed following the ruling of the courts, referred to in Chapter III, that the telephone was a telegraph within the meaning of the Telegraph Acts.

The opening of the Bell Telephone Exchange in Queen Street was immediately followed by the entry of a third party into the telephone field, viz., the Edison Telephone Co., who established an exchange in South Exchange Place.

The National Telephone Co., formed on March 10th, 1881, for the purpose of telephonically exploiting Scotland, as well as part of the English Midland Counties and Ireland, acquired Messrs. D. and G. Graham's business as from February 9th,

1881, and at about the same time the businesses of the other two competitors were absorbed by the same company.

Although not directly associated with telephony, as already indicated, electric lighting was frequently undertaken by the same firm also supplying telephone service and Mr. David Graham's association with the introduction of electric lighting by means of the incandescent lamp into Glasgow and various parts of Scotland will, therefore, not be without interest. For some years previous to the period under review he was engaged in carrying out a considerable amount of work for the late Lord Kelvin, then Sir William Thomson, who, incidentally, was associated with the early telephone companies and acted as their consulting electrician for many years. The first residence to be electrically lighted as a practical proposition, Mr. Graham says, was that of Sir William Thomson, situated at the Glasgow University, and the wiring of the building was executed by Messrs. D. and G. Graham.

On March 16th, 1881, when Mr. Joseph D. Swan, whose name is associated particularly with the filament electric lamp, addressed the Philosophical (now Royal) Society of Glasgow on his method of electric lighting by an incandescent lamp, Messrs. D. and G. Graham, who were described as telegraph engineers of Sauchiehall Street, were responsible for the generation of the requisite electric current for Mr. Swan's demonstration, and for conveying it from their Clarence Works to the rooms of the Society.

The first electric lighting installation in the world for mines was fitted by Messrs. D. and G. Graham at Earnock Colliery, near Hamilton, in 1881. It was officially inaugurated on August 9th, 1881, and an account of the opening ceremony appeared in the *Glasgow Herald* published on the following day. Telephone communication was also established, at the same time, between the engine-room and the pit bottom by the same firm.

The Philosophical Society of Glasgow, in connection with the exhibition held under their auspices in 1880, bestowed upon Messrs. D. and G. Graham " The Special Award for Their Collection of Apparatus for Utilisation of Electricity for Domestic, Telephone, and Mining Purposes," and in recognition of his pioneer work in electrical engineering generally, the Association of Mining Electrical Engineers conferred upon Mr. David

Graham the exclusive distinction of honorary membership of their Association.

In the county of Yorkshire the story of the telephone opened almost simultaneously in the two important industrial centres of Sheffield and Halifax, where the telephone was taken up vigorously at an early date and considerable enterprise was exhibited by local gentlemen in its application to commercial uses, its technical improvement, and development. The author has been fortunate in securing information of interest regarding early telephone activity in these two towns, and is largely indebted to Messrs. Taskers Engineering Co., Ltd., of Sheffield, for the particulars he is enabled to present concerning the early exploitation of the telephone in that town. The business conducted to-day by Taskers Engineering Co., Ltd., of Sheffield, has been built up from the business originally established by Mr. John Tasker, whose name was identified with the introduction into Sheffield of the telephone as a practical project in 1879.

John Tasker was a native of Sheffield, and started life in the boot and shoe business. In 1837 he founded the firm of Tasker, Sons and Co., rubber and leather factors, of Angel Street, Sheffield, and soon after its formation added to the business a mechanical engineering department which ultimately developed into the firm at present known as Taskers Engineering Co., Ltd.

As is well known, the industrial activities of Sheffield are largely concerned with the construction of ordnance and manufacture of armour plate, and as an illustration of the enterprise and progress made by this firm the author is informed that, as far as can be ascertained, the whole of the armour plates on every naval boat engaged in the late world trouble of any belligerent or non-belligerent nation were ground on Taskers' patent armour plate grinding machines. These machines, having established a world-wide reputation, are at work at all the leading armour works and arsenals both at home and abroad.

Mr. John Tasker was the inventor of children's bouncing balls, and was the first to discover how to repair goloshes, which he imported from America, by means of gutta percha. Thus in Sheffield, as in many other places, the business of electrical engineering really developed out of a business largely concerned with india-rubber and gutta percha, a fact which, perhaps, is

not surprising in consideration of the important part played by those two substances as insulation for electrical conductors.

Mr. Tasker became interested in the telephone very soon after the introduction into this country of Graham Bell's patent, and in 1879 the first telephone exchange in Sheffield was opened on the premises of Messrs. Tasker, Sons and Co., in Angel Street, and a telephone department of the firm was established. The exchange was opened with about a dozen subscribers, amongst whom were the two local newspapers, the *Sheffield Telegraph* and the *Sheffield Independent*, the annual rental first charged for exchange service being £7. The earliest instruments were fitted with two Bell telephones, one of which served as receiver and the other as transmitter, but at a later date a number of transmitters of the Crossley type—to be referred to later—were installed. The switching arrangements consisted of a Williams sliding spring-peg switchboard supplied by Messrs. D. and G. Graham, of Glasgow, a device extensively used throughout the country in the early stages of telephone development, and described briefly in a later part of this chapter.

Mr. John Tasker was evidently a man of advanced ideas, and held the opinion that his native town should possess and work its own telephone and electric lighting systems, as well as its own gas and water undertakings. In addition to the enterprise shown by Mr. John Tasker as the pioneer of the telephone in Sheffield, he was also instrumental in establishing a system of electric power supply, and in connection with his business organised an electrical department for the supply of electric current to Sheffield consumers, working it in conjunction with the telephone department. The first electric power plant to be installed for public supply of electrical energy in Sheffield comprised a pair of compound condensing engines by Messrs. Goodfellow, of Hyde, driving dynamos supplied by the American Thomson Houston Co.

The electric light and telephone business ultimately became known as the Sheffield Telephone Exchange and Electric Light Co. This company was formed in 1881, and Mr. George Franklin, chartered accountant of Sheffield, who later became President of the National Telephone Co., Ltd., was intimately associated with its formation.

Mr. W. Johnson, previously a telegraph engineer for the Post

Office in the Mansfield district, became manager of the company, and under his able and energetic administration a thriving business was built up. Mr. W. Johnson invented the carbon pencil transmitter which bears his name, and is described and illustrated in Chapter XVII. This transmitter was used extensively by his company in Sheffield, and also in some other parts of the country. An illustration of an early form of table telephone instrument, fitted with a Johnson transmitter, as used in Sheffield, from a photograph loaned to the author appears in Fig. 43. A wall instrument of similar parts was also employed.

One of the first types of receiver to be used in Sheffield is illustrated in Figs. 156 and 157. It was commonly known as the " Potato masher " and consisted of a mahogany case made in three parts, stem, body, and ear-piece. The body was secured to the stem by a substantial brass washer, provided with a bush for reception of the stem. Although a single pole receiver, the magnet was not of the usual bar form, but was made of a **G**-shaped piece of steel, carrying a central pole piece of soft iron, for reception of the wire coil. The shape of the magnet may be discerned from one of the receivers shown in the illustration. These receivers were probably made by Messrs. Blakey and Emmott, of Halifax. The illustration has been prepared from a photograph of two receivers presented to the author by Mr. F. W. Best, of Rochdale.

The period of competition which ensued with the National Telephone Co. and the subsequent acquisition by that company of the telephone business established by Messrs. Tasker, is dealt with in Chapter VI.

In mid Yorkshire the gentlemen who were most intimately concerned with the introduction of the telephone and its adaptation in the public interest were Messrs. Walter Emmott, Edwin Blakey, and Louis John Crossley. The author is largely indebted to Mr. Walter Emmott, now Consulting Electrical Engineer of Halifax, through inquiries kindly conducted by Mr. F. W. Best, of Rochdale, for much of the information which follows relative to the introduction of telephony into the neighbourhoods of Leeds, Bradford, and Halifax.

Mr. Emmott became interested in Graham Bell's invention soon after its publication, when he entered into an agreement with the representatives in England of the inventor, by which

he was appointed sole representative for the counties of Yorkshire and Durham. Mr. Emmott eventually entered into partnership with Mr. Edwin Blakey, and on the inception of the telephone exchange he centred his attention more particularly on this branch of the industry, and was the prime mover in introducing the telephone for exchange purposes, more particularly in Leeds, Bradford, Halifax, and other neighbouring places.

Messrs. Blakey and Emmott commenced business in Halifax on January 1st, 1878, and, although the partnership has since been dissolved, and the firm is now defunct, it ultimately became one of the leading electrical engineering concerns in the north of England and actively engaged, not only in the exploitation of the telephone in its application to private and public telephone service, but also in the manufacture of telephone and other electrical apparatus of various descriptions.

There were no microphonic transmitters in the days when Mr. Emmott entered the telephone field and in the first telephone installations to be fitted Bell telephones were employed, both as receiver and transmitter. Mr. Emmott was well acquainted with Professor Hughes, the inventor of the carbon pencil microphone. He was also closely associated with Mr. Louis John Crossley, of Halifax, who invented the first carbon pencil microphone to be brought into commercial use successfully as a telephone transmitter, and was engaged as his electrical assistant for a number of years, prior to entering into partnership with Mr. Blakey. On Mr. Crossley's behalf Mr. Emmott actually took out the patent for his transmitter, which is described in British Patent Specification No. 412, of February 1st, 1879, and Messrs. Blakey and Emmott subsequently acquired the sole rights for its manufacture. Mr. Louis John Crossley, in the period under review, possessed the reputation of being one of the most successful electricians in the country. In the *Manchester Courier* for April 14th, 1879, appeared an interesting account of an experiment conducted by Mr. Crossley; it was amongst the earliest satisfactory attempts to telephone over comparatively long distances. A Crossley transmitter, with the necessary battery, situated in the pulpit of the Square Congregational Chapel, Halifax, was connected by means of an ordinary telegraph wire, existing between Halifax and Manchester on the Lancashire and Yorkshire Railway, to Bell telephone

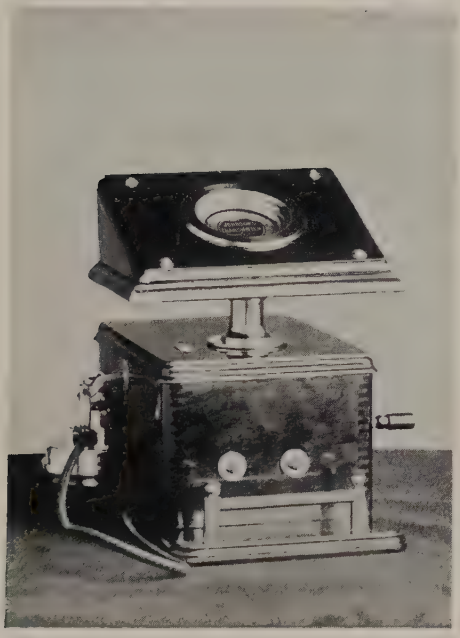

FIG. 43.—Table Instrument with Johnson Transmitter as employed by Tasker and Sons, of Sheffield.

(From a photograph supplied by Mr. P. N. Pilling.)

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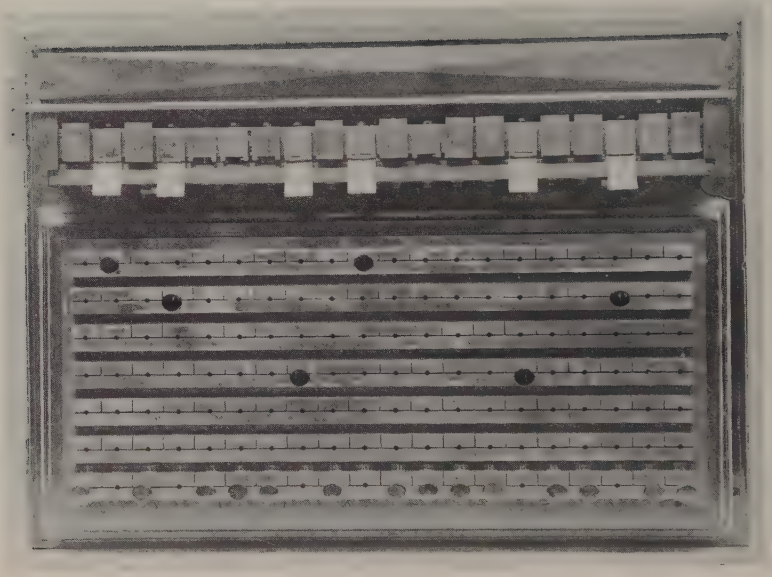

FIG. 44.—Blakey-Emmott Switchboard for 25 lines.
(From a photograph supplied by Mr. F. W. Best.)

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receivers at Manchester. Conversation between the two places over the 36 miles of wire which intervened proved to be quite satisfactory, and the words uttered by the officiating minister at Halifax, the lessons and the sermon, as also the music of the organ and the singing of the congregation were transmitted to Manchester with success. Mr. Emmott was in charge of the technical details of the experiment, which at the time was regarded as a remarkable achievement of long distance transmission and gave rise to considerable comment in the American Press.

Mr. Emmott was well acquainted with Sir William Preece, then Mr. W. H. Preece, by whom the Crossley transmitter was adopted as the standard instrument to be employed by the Post Office, and Messrs. Blakey and Emmott manufactured and supplied it in large quantities to that administration, as well as to the National Telephone Company, to railway companies for use in their signal cabins, and to various other firms. The Crossley patent was eventually purchased for £20,000 by the United Telephone Company, for whom Messrs. Blakey and Emmott continued its manufacture.

In addition to their enterprise in telephony, Messrs. Blakey and Emmott were pioneers in electric light and power, Halifax being one of the first towns lighted by them; they also undertook the execution of contracts for electric lighting and power works in various parts of the country and abroad.

At a very early date in the history of the telephone in this country Messrs. Blakey and Emmott commenced the manufacture of an apparatus for telephone switching known as the Blakey-Emmott switchboard, which they supplied to various telephone and railway companies during the period 1879 to 1885. By the courtesy of Mr. Walter Emmott, and of Mr. F. Beaumont, of the Lancashire and Yorkshire Railway Company, through the kind offices of Mr. F. W. Best, of the Post Office Engineering Department, it has been possible to secure information regarding and particulars of the design of this switching device, and a photograph of a Blakey-Emmott switchboard is reproduced in Fig. 44. This particular switchboard was only thrown out of service by the Lancashire and Yorkshire Railway Company in the latter part of 1920, and it must have given satisfactory service for a period of something like 35 years, no

mean performance for a telephone switchboard. A diagram of the electrical connections, kindly supplied by Mr. Best, is given in Fig. 45, and it will be seen that the principle underlying the design is that of the Umschalter switch, and that the

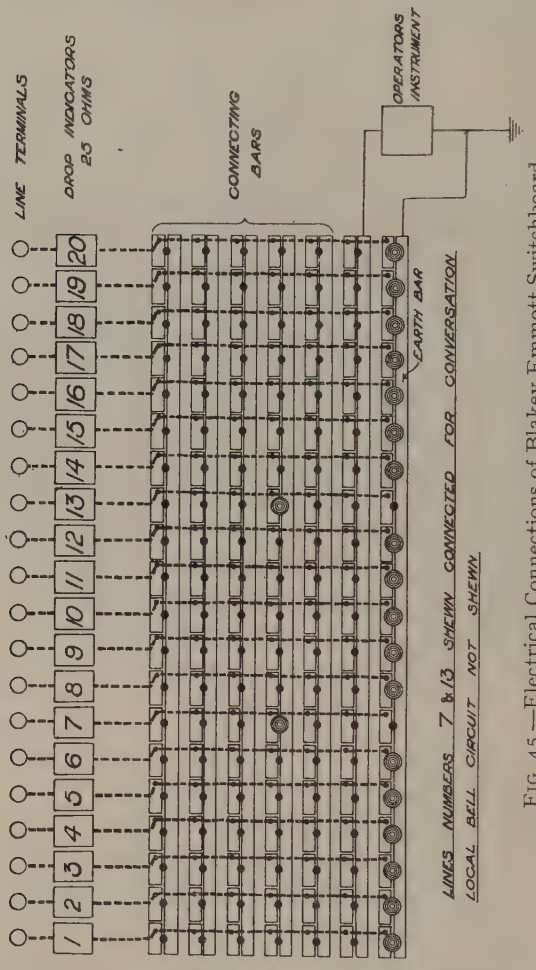

Fig. 45.—Electrical Connections of Blakey-Emmott Switchboard.

device resembles in many respects the switchboard introduced by the Edison Telephone Company of London. It appears, however, to be an improvement on the Edison switchboard, principally inasmuch as the vertical bars to which the incoming subscribers' lines were connected in the Edison pattern switch were, in the Blakey-Emmott switchboard, formed of a series

of blocks or segments, wired together, instead of a continuous half-lapped bar, as may be seen from the photograph and diagram.

The apparatus comprising the 20 line switchboard was mounted on a mahogany baseboard measuring 2 ft. 8 in. × 1 ft. 11 in. The incoming single line wires were connected to a row of terminals fixed in the backboard, behind a hinged cornice, from whence connection was made to the drop indicators mounted in one row immediately below. These indicators had two coils wound to a total resistance of 25 ohms. They were provided with heavy rectangular shutters of solid brass, normally held in a vertical position by a catch and detent, upon which appeared in bold red figures the subscribers' numbers. The end of the armature of each indicator was screwed into an adjustable brass ball which acted as a counter balance and, upon cessation of the current circulating in the coils, restored the armature to its normal position. On falling, the shutter disclosed the subscriber's number painted in red on the brass frame of the coils, and made contact with a brass strip, which may be discerned in the photograph, fitted below the row of indicators, thus completing a local bell circuit for the purpose of securing the attention of the switchboard attendant. The indicator shutters were restored by hand. Below the indicators were provided seven pairs of horizontal brass bars; the lower one of each pair was continuous throughout the length of the board, the upper one being divided into 20 equal portions, wired as shown in the diagram. Circular brass pegs, inserted into holes situated between the continuous bars and each of the segments immediately above them, provided means of connecting together any two lines, as might be required. The lowermost, or seventh bar, was permanently connected to earth, and brass pegs normally inserted in the holes provided in this bar earthed all lines through their respective indicators. The sixth horizontal bar was connected to the switchboard attendant's telephone. The remaining five bars were for connecting purposes, thus providing 50% through switching facilities, this being regarded as sufficient. The method of operation of the switching device will, no doubt, now be clear.

Two 20 line switchboards of Blakey and Emmott design and manufacture are, at the time of writing, still in use at Messrs. Crossley's carpet works at Dean Clough Mills, Halifax.

Early telephone business executed by Messrs. Blakey and

Emmott included the provision of private telephone lines in various parts of the district. Telephone exchanges were first opened in Bradford and Halifax and communication was established between these two towns by means of trunk wires erected by the firm. Single lines with earth return were at first exclusively used, No. 11 galvanised iron wire being employed as line wire.

In 1880 Messrs. Blakey and Emmott extended their operations further afield, and in July of that year the first telephone exchange in Leeds was inaugurated by them. It was opened with about 30 subscribers, and was situated in the Royal Exchange. The switching equipment was a switchboard of the Blakey and Emmott type already described. The terms of subscription to Messrs. Blakey and Emmott's exchange service were £12 per annum.

The City of Leeds was saved from the disadvantages attendant upon the operation of rival telephone systems by the timely action of the Mayor, and therefore competition between opposing parties did not take place in that important city. The United Telephone Co., not content with its conquests elsewhere, appeared on the scene at Leeds in 1880, apparently intent upon instituting a rival telephone service to that already established by Messrs. Blakey and Emmott, and requested that the Mayor should convene a meeting of business men, for the purpose of giving consideration to the question of the provision by them of a telephone exchange for Leeds. The Mayor's reply was to the effect that an exchange was already in operation by Messrs. Blakey and Emmott, and that Leeds did not require two such exchanges; he suggested a meeting between the representatives of the United Company and Messrs. Blakey and Emmott, with a view to some mutually satisfactory arrangement being arrived at which would avoid objectionable rivalry in the provision of telephone service.

The Mayor presided at the meeting subsequently held, and the upshot was that the United Telephone Company purchased Messrs. Blakey and Emmott's business as it stood, including the systems working at Bradford and Halifax. Mr. J. C. Chambers, who ultimately became superintendent of the National Telephone Co.'s Northern District, with headquarters at Leeds, was first identified with the United Telephone Company on

July 29th, 1880, when he was appointed manager at Leeds; in August of the same year an exchange, fitted with a switchboard of the slipper-jack type, similar to the first London switchboard employed at 36 Coleman Street, London, E.C., already described and illustrated, was opened in Commercial Buildings, Leeds, and the subscribers to Blakey and Emmott's exchange were ultimately absorbed in the United Company's system.

In course of time, the United Company's interests in Leeds passed, successively, into the hands of the Yorkshire Telephone Company, the Provincial Telephone Company, and upon its formation in 1881, the National Telephone Company.

Mr. Louis John Crossley, whose name was so intimately associated with the early use of the telephone in Halifax, and still more so with the transmitter identified by his name, died at Halifax on August 30th, 1891. He was one of the earliest members of the Society of Telegraph Engineers and a Fellow of the Royal Meteorological Society. He was the owner of Dean Clough Mills, the largest carpet works in the world at the time the story of the telephone opened. As early as September 1879 Mr. Crossley opened up telephone communication between Milner Field, the residence of Mr. Titus Salt, and Moorside, Halifax, his own residence, and Broomfield, Halifax.

In October 1879 a telephone exchange was opened in Edinburgh, Mr. J. G. Lorrain again being the moving spirit. Eventually he was successful in bringing about the formation of a company, known as the Scottish Telephonic Exchange, Ltd., created with a paid up capital of £10,000 for the purpose of furthering the advancement of telephony in that locality. Progress was not rapid until, as Mr. Lorrain explained, Mr. Faithful Begg took an interest in the company. The original telephone exchange was in St. Andrew's Square, but two other exchanges in different parts of Edinburgh and also an exchange at Leith were opened almost simultaneously.

The switching apparatus installed at these exchanges differed from that of the "Williams" type. It consisted of one or more "Jones" switchboards manufactured by Jones Bros., of Cincinnati. The early type of Jones switchboard was a modified form of the Umschalter switch, similar in principle to the Edison peg switchboard previously described. It comprised a set of upright and a set of horizontal bars; its special feature was the

peg, shaped like a key, and fitted with a spiral spring. The peg passed through a slot formed in the front bar and by giving it a half turn it was locked in position and there retained by the pressure of the spiral spring. Where the number of subscribers exceeded the maximum of 50, accommodated on one board, additional similar boards were used, connections between them being effected by means of flexible connecting cords. These boards were considered by some to be an improvement on the "Bell" switchboard; it was claimed that the interchange of verbally expressed information was largely dispensed with, and that this contributed to the quiet and orderliness of the switch-room.

The Scottish Company also introduced the telephone into Dundee.

To the Scottish Telephonic Exchange, Ltd., belongs the credit of introducing the telephone into Ireland, for in the early part of 1880 it sent over three gentlemen, of whom Mr. R. Shepherd, later superintendent for the National Telephone Company's North-Eastern Province (after retirement of Mr. Claxton), was one, to open up a telephone service in Belfast. Mr. J. G. Lorrain acted as consulting engineer. The telephone was practically unknown in Belfast at this time. A demonstration line was fitted up and free service for three months offered to 50 firms. An exchange was shortly afterwards established at No. 2 Castle Chambers, where a 50 line switchboard manufactured by Jones Bros., of Cincinnati, was installed. This was the first exchange to be established in Ireland, and service was continued with the loss of only two or three subscribers at the end of the three months, at a tariff of £20 per annum.

The business of the Scottish Telephone Exchange, Ltd., together with that of their competitors, the United Telephone Company, who followed them for competitive purposes to Belfast, passed into the hands of the National Telephone Co., Ltd., on that company's formation.

The telephone was introduced into Birmingham in 1879, and in November of the same year a company was formed for the purpose of instituting exchange service. The Midland Telephone Co., Ltd., opened the first exchange in Birmingham at the end of December 1879. The exchange was situated in Exchange Chambers, New Street, and at the outset accommo-

dated less than a dozen subscribers, granted free service on trial for a period of three months, with the added inducement that the service might be retained at the end of that period, at a rental of £10 per annum instead of the standard rate of £20.

Mr. Fred. Ormiston, previously the engineer and electrician of the Telephone Co., Ltd., was consulting electrician to the Midland Company.

The switching mechanism first fitted resembled that at 36 Coleman Street, London, E.C., but only one connecting panel and one operating table were provided.

One boy operator only was employed. There were at first no ring-off signals, as the indicators were connected between the lower contact of the slipper-jack and earth. Later on the table connections were cut out, and fleeting contacts were tried on subscribers' instruments to avoid the trouble caused by subscribers failing to give a clearing signal. In October 1880 there were 81 subscribers in Birmingham, and an exchange known as " Jewellers," situated in Frederick Street, was opened. This exchange served the district in which the jewellers' industry preponderated and a special rate was introduced for the benefit of jewellers who did not desire communication with subscribers other than those connected to the " Jewellers " exchange.

In 1886 the number of subscribers in Birmingham had increased to 312. The Midland Telephone Company's business was acquired by the Provincial Telephone Co., Ltd., and was passed on to the National Telephone Company on the formation of the latter.

The Midland Telephone Co., Ltd., extended their operations to Wolverhampton, and opened an exchange there early in 1880; in October of the same year there were 18 subscribers.

In Preston, Lancashire, telephone exchange service was instituted almost simultaneously by two opposing parties. The Lancashire and Cheshire Telephonic Exchange Company opened an exchange in Lancaster Road during the first week of August 1881, and within the course of a week or two a competitive exchange was opened at No. 7 Fisher Gate by Mr. G. Sharples, who carried on business as a chemist and electrician under the title of Sharples and Company. Messrs. Sharples' original rate of £6 per annum for exchange service was eventually raised by £2. Active competition ensued for some years; the ultimate

absorption of Messrs. Sharples' business by the Lancashire and Cheshire Company is referred to in Chapter VI.

Messrs. Sharples were the defendants in an action brought against them by the United Telephone Company, and a perpetual injunction was granted restraining the defendants from infringement of the plaintiffs' patents.

The telephone was first introduced into Bristol in March 1879, and the establishment of an exchange was at once given consideration. Sufficient support was forthcoming, and an exchange fitted with a slipper-jack switchboard commenced to give service in December 1879 with about 25 subscribers; this number had increased to 100 by April 1881.

The introduction of the telephone into the Isle of Man in 1881 is described by Mr. G. Gillmore in a short article headed "Telephony in the Isle of Man," published in the *National Telephone Journal* for May 1906, and reading as follows :—

"When I came to the Island some 25 years ago, the Manx people knew nothing about telephones or telephone exchanges. From the business being done in Douglas (the principal town) I saw that an exchange system was needed. I applied to the Government, and succeeded in obtaining one of the few old licences which covered the whole of the British Isles. I then tried to get the natives to sign agreements to take telephones, but could not get a single one to do so, and at the finish I had to set up a number of free lines to educate the people into the thing. I succeeded in doing this after two years' hard work and was getting on nicely when my telephone instruments (which I had purchased from the New Telephone Company) were seized and confiscated through some patent action. I had then to arrange with the Lancashire and Cheshire Telephone Company to hire me some telephones, which carried me over till the patents ran out, when I was able to buy in open market again."

The United Telephone Company now owned the provincial exchanges established by the two parent companies in the provinces and immediately extended its operations to other provincial towns.

In Plymouth an exchange was opened in July 1881 with about 60 subscribers on trial for a limited period. The company failed to secure a licence before opening the exchange and, under a threat of legal proceedings by the Postmaster-General the exchange was closed on October 31st, 1881; it was reopened

in February 1885 after a statement in the House of Commons on August 8th, 1884, that licences would be granted to telephone companies. The Post Office opened an exchange in Plymouth on December 15th, 1881.

The telephone was introduced into Brighton at The Brighton Exhibition of 1881. Messrs. M. Volk and Co. were appointed agents for the United Telephone Company. They were electrical manufacturers and contractors and undertook the construction of electrical apparatus of various descriptions for the United Company. The telephone exchange opened in West Street, Brighton, in 1882, was the first to be permanently established on the South Coast of England.

It is interesting to note that Messrs. M. Volk and Co. constructed at Brighton the first electric railway in Great Britain; it was also the second in the United Kingdom, and was laid along the foreshore. The first in the United Kingdom was at Portrush, in the North of Ireland, but whereas on this railway electricity gave way to steam, reverting again to electrical working at a later date, the Brighton line continued to be worked electrically and was eventually extended to Rottingdean.

In Dublin the United Telephone Company opened an exchange in 1881. The switchboard was similar to that first fitted at 36 Coleman Street, London, and illustrated in Figs. 5 and 6. An Edison peg board was fitted later. The company's offices were in Commercial Buildings, Dame Street.

The first exchange in Nottingham was situated in Bottle Lane and was opened with two subscribers and a Gilliland switchboard in November 1881.

The United Telephone Company commenced operations in Sunderland early in the year 1880.

Sunderland is of special interest, as it was in that town that the telephone was first introduced to the North of England, and it may therefore claim to be the pioneer town, in so far as the adoption of the telephone is concerned in the northern district. The exchange was established in Arcade Chambers, High Street, West. Service was first instituted by means of a 25 line Williams sliding spring-peg switchboard, an adaptation of the Umschalter switch principle; the capacity was increased at a later date by the addition of a second similar board, the sets of horizontal rods being connected together, or multipled, to admit of con-

nections between the lines of subscribers terminated on one board and those on the other. The development was such that these boards did not serve for very long and they were replaced by the switching arrangements shown in the photograph reproduced in Fig. 46. This switchboard was known as "Irish's" board, Mr. W. E. Irish, its designer, being manager for the United Company at the time it was installed.

So far as is known, it was the only board of its type ever fitted in this country, or elsewhere, and as it possesses certain unique features, as a switching device of the period it possesses particular historic interest and merits brief attention. It will be observed that the board is somewhat similar in appearance to the one originally fitted by the Bell Company at 36 Coleman Street, London, and the method of operation was also in some respects similar.

Mr. Irish took out a patent for his board in 1882; particulars of the connections are given in detail in Fig. 47.

There were two connecting panels, or sections; each accommodated 4 rows of 25 indicators and slippers, making a total fitted capacity for 200 lines. The novel feature was the rotary switch, of which four were provided; they were accommodated on a long table, situated in front of the connecting panels. Each rotary switch was provided with fifty metallic studs, one for each subscriber's line. Each stud normally rested upon a spring fitted beneath the table and provided with both a back and a front contact. The rotary arm of the switch was connected to the operator's speaking instrument, and carried a ringing key. The connections will be readily followed from the diagram, Fig. 47.

There were five operators, one for making the cord connections on the switchboard and one to operate each of the four rotary switches and to converse with the subscribers. On observing an indicator shutter to fall the table operator controlling the group of lines which included the calling subscriber's line rotated the arm of his switch until its contact was immediately above the stud corresponding to the number of the calling subscriber's indicator; depression of the switch arm then put him in communication with the calling subscriber, from whom he ascertained the number of the subscriber wanted. While the calling subscriber waited, the operator rotated the arm of the switch and depressed it when it arrived over the stud corresponding to the

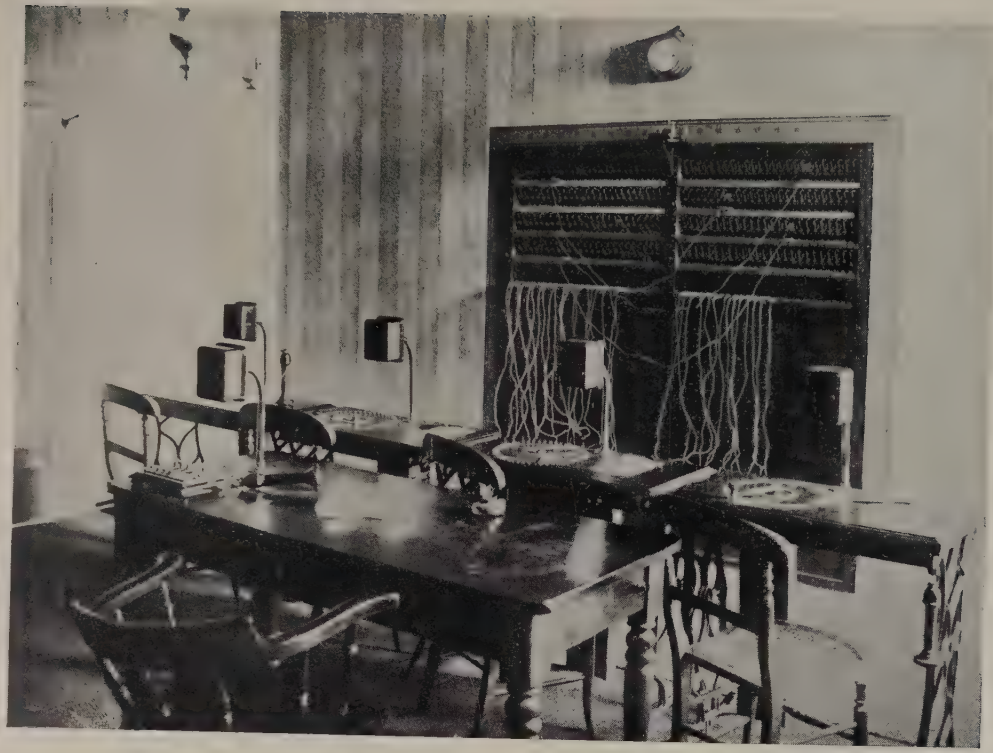

FIG. 46.—Sunderland Telephone Exchange; Irish's Switchboard, 1882.

(From a photograph loaned by Mr. H. Kitchen.)

[*To face page* 112.

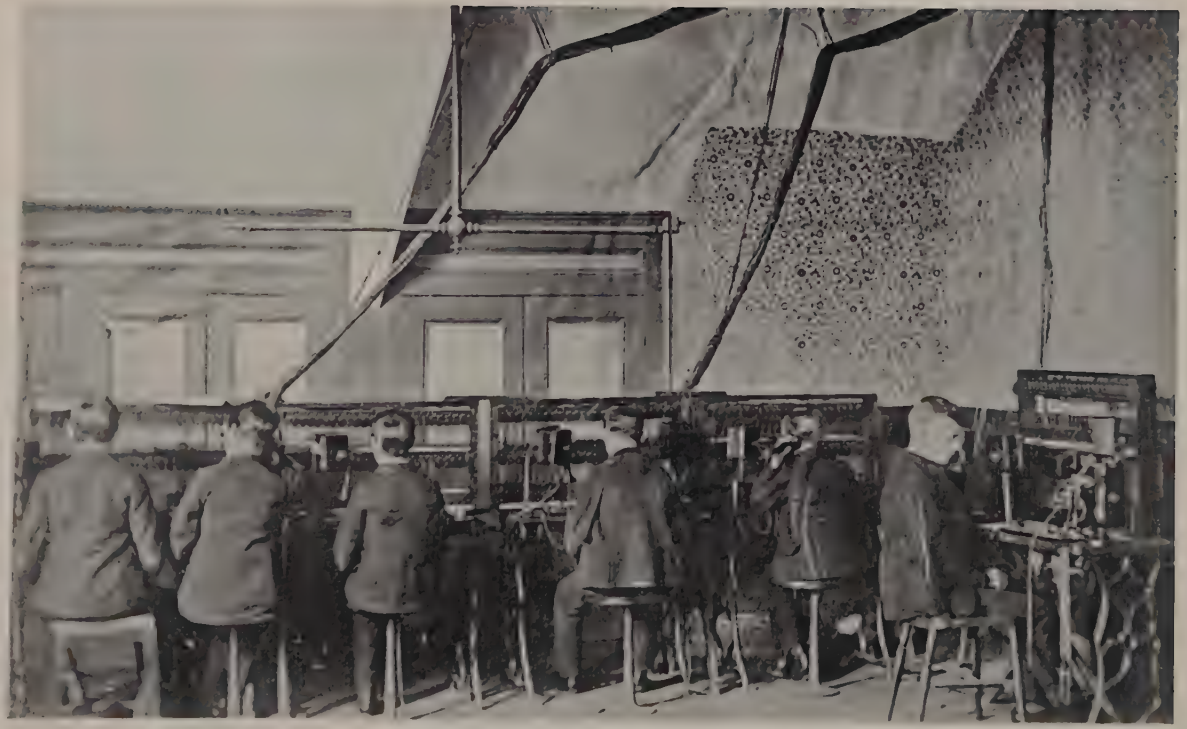

FIG. 48.—Temporary Switching Arrangements with boy operators. Sunderland, 1886.
(From a photograph lent by Mr. C. B. Clay.)

[*To face page* 113.

number of the subscriber to be called. He then depressed the ringing key and thereby rang the bell of the subscriber required. On gaining his attention, the table operator verbally informed the operator at the connecting panel of the two numbers waiting

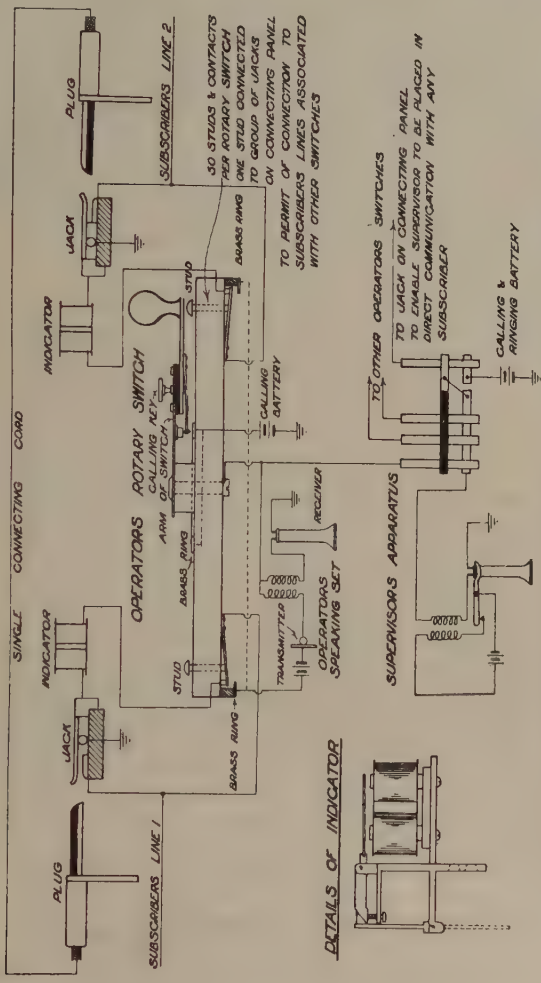

Fig. 47.—Electrical Connections of Irish's Switchboard. Sunderland, 1882.

for connection, and the latter operator placed them in connection by means of a single flexible cord provided at each end with a plug consisting of a flat spring of brass mounted on a piece of vulcanite. The connection was thus established, and the two subscribers were enabled to converse. On the indicator again

falling, denoting cessation of the conversation, the normal state was restored by removal of the cord and plugs.

One of the contacts on each rotary switch was reserved in order to permit of communication with subscribers not connected thereto, this stud being connected for that purpose to special jacks mounted on the connecting panel. It will be observed that the arrangement of the plugs and connections was such that only one indicator was left in circuit during conversation. The calling was by battery. Blake transmitters and Bell receivers were used. The front table was a supervisor's table and the keys mounted upon it, seen in the illustration, were to enable connection be be made between the supervisor's telephone and the dial switches.

This board was demolished in the summer of 1885 and gave place to the latest type to date of Western Electric Company's multiple switchboard with answering jacks, the transition period being provided for by means of the temporary switchboard shown in Fig. 48.

It is impossible to give descriptions of or even to mention all the various types of plant and apparatus employed by the early provincial telephone undertakings. Original and novel devices of various descriptions were devised and brought into use. Many of these involved the owners in litigation, brought about by the United Telephone Company, who were in possession of the controlling patents.

The switching devices adopted in the first exchanges opened in this country were for the most part importations from America.

A switching device somewhat extensively used in the early days of telephony in the provinces was the "Williams sliding spring-peg switchboard," and as this appliance has been mentioned in comnection with Sheffield and Sunderland, it will be briefly described at this juncture.

This ingenious board hailed from America, and was made by Mr. C. Williams, jun., of Boston. Like many other boards manufactured at this time, it was an adaptation of the principle of the Umschalter switch. Fig. 49 illustrates in diagram form the general arrangement of parts and connections of the contrivance. Each subscriber's line was connected to one of a series of vertical brass bars. Behind the vertical bars were horizontally arranged a number of cylindrical brass rods used for

connecting purposes. Each of the vertical bars was fitted with a sliding peg which could be moved up and down upon the bar, so that contact could be made with any one of the horizontal bars. A V-shaped cut was formed in the end of the peg in order to facilitate connection, and stable electrical contact was ensured by

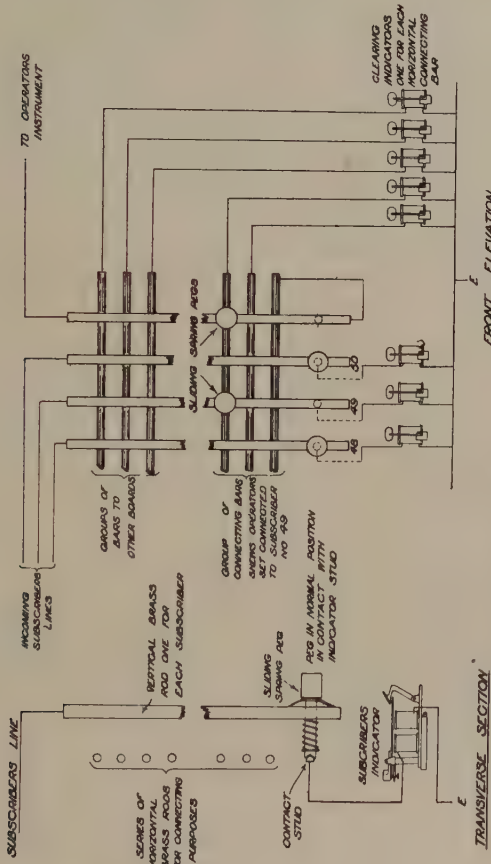
TO OPERATORS INSTRUMENT
CLEARING INDICATORS ONE FOR EACH HORIZONTAL CONNECTING BAR
SLIDING SPRING PEGS
GROUP OF CONNECTING BARS NORMALLY DISCONNECTED TO SUBSCRIBERS NOS 41 TO 50
GROUPS OF BARS TO OTHER BOARDS
INCOMING SUBSCRIBERS LINES
VERTICAL BARS ONE FOR EACH SUBSCRIBER
SLIDING SPRING PEG
PEG IN NORMAL POSITION IN CONTACT WITH INDICATOR STUD
SUBSCRIBERS LINE
SERIES OF HORIZONTAL BARS ONE FOR EACH SUBSCRIBER FOR CONNECTING PURPOSES
CONTACT STUD
SUBSCRIBERS INDICATOR
FRONT ELEVATION
TRANSVERSE SECTION

Fig. 49.—Electrical Connections of Williams' sliding spring-peg Switchboard.

pressure exerted by a spiral spring fitted on the peg as shown in the diagram. Normally the peg rested upon a contact stud connected to earth through the windings of the subscriber's indicator. The indicators used were of similar type to those illustrated in Fig. 6, but were probably of higher resistance. A vertical bar and spring peg were provided for the operator's instrument for operating purposes. An earthed clearing indicator

was connected to each horizontal rod and therefore for every connection between two subscribers made upon the board one clearing indicator was connected in shunt to earth. The operator's instrument was also connected to one of the horizontal rods. When the number of subscribers was more than could be accommodated on one board, some of the horizontal rods were reserved for connection to similar rods situated upon other boards in the same exchange.

In the preparation of this chapter the author has made exhaustive inquiry to discover the dates when telephone exchange service was first given in the more important towns and cities in the United Kingdom. Unfortunately, however, the entry of the telephone into the provinces is shrouded in a good deal of uncertainty, and the absence of authentic records has rendered it particularly difficult, and in many cases impossible, to quote reliable dates.

At the outset the telephone began to grow from very small beginnings and without very much advertisement. In the commencement private line services only were provided either for sale outright or on rental terms, and it is possible that in some cases exchange service developed gradually out of the private wire systems built up previously.

The opening of the earlier exchanges was accomplished unobtrusively and quietly and without that ceremonial announcement of the fact which generally accompanied the opening of an exchange in later years. Consequently, few records exist to indicate reliably the dates and events which marked the introduction of telephony into the provinces, and the order in which the various towns concerned should be placed in regard to the establishment of telephone exchange service. Disparity exists, even in the few records available and there is difficulty therefore in arriving at conclusions in respect of the sequence of events accompanying the introduction of telephony into this country. Several different and competitive firms were sometimes concerned, and it is probable that dates have been quoted in reference to one company to the exclusion of the others.

In Chapter II the telephone exchange at 36 Coleman Street, London, E.C., is referred to as the first exchange in this country; the date of opening is given as August 1879, a date generally accepted as correct. There is, however, an element of doubt

as to whether the Coleman Street exchange may rightly be regarded as the first to be opened; at various times there has been some discussion on the matter, but the question still remains unsettled. It is not proposed to enter into lengthy examination of the problem, as by so doing no useful purpose will be served, but the following extract from the pages of the *National Telephone Journal* for January 1910, where the question is discussed, is interesting :—

"The first exchanges, however, unlike the earliest railways, were not opened with the accompaniment of flags, brass bands, banquets and speeches, although as soon as the importance of the telephone began to be appreciated the installation of new exchanges in large towns was sometimes signalised by public ceremonies. The part which the supposed 'scientific toy' was to play in civilisation was not appreciated in the year 1879.

"Another difficulty which confronts the investigator is that in some cases at least there was probably no formal opening of the first exchange. At some period between the time when work was first commenced on the switchboard and the time when a fair number of subscribers enjoyed telephonic inter-communication, there would be a stage when half a dozen subscribers were receiving *bona fide* exchange service. Hence the first of these dates would be too early and the second too late to be fixed as the actual date of opening. We have been at some pains to collect evidence on the subject, and what is indisputably established appears to be that in September 1879 exchanges were working in Coleman Street and Lombard Street, London, and in Faulkner Street, Manchester, with not more than about thirty subscribers between them, and that exchanges in Liverpool, Wolverhampton, and Sheffield followed in quick succession. Mr. J. G. Lorrain is of opinion that he had the Manchester Exchange working in the July of the year mentioned, whilst Mr. Poole would put it at some date in September; Messrs. Fletcher and C. J. Phillips can testify that the Coleman Street Exchange was working in August 1879; and Mr. J. E. Kingsbury produces evidence that the Lombard Street Exchange was publicly opened in September, but has no doubt that service was given for some time previously. Further, a correspondent in the *Electrical Review* of December 17 states that the latter exchange was established in September 1878, and gives a photograph of its switchboard and a list of its six subscribers. This, however, does not appear to be a switchboard in any recognised sense of the term. It is only an electric bell indicator board by means of which it would not be possible to put subscribers in communication with one another. We are therefore not much nearer the solution of the question; personal

evidence is conflicting, and all that documentary evidence has established so far is that there is very little to choose between the claims of the three exchanges in London and Manchester to priority."

In the discussion which followed the reading of a paper by Mr. J. E. Kingsbury before the Institution of Electrical Engineers on January 24th, 1895, entitled "The Origin and Development of the Telephone Switchboard," Mr. James G. Lorrain, one of the pioneers of the telephone in this country, stated that he erected the first "Bell" switchboard in this country at Manchester, and opened the exchange in that City in July 1879, which was about a week or a fortnight in advance of the London exchange; he continued by saying that the Liverpool, Sheffield and Wolverhampton exchanges followed in quick succession.

Mr. Lorrain's statement is borne out by a paragraph in the *Electrician* for January 3rd, 1880, referring to a prospectus issued by the Scottish Telephone Exchange, Ltd., which included a statement to the effect that the first telephone exchange in this country was started in July 1879 at Manchester. Mr. Lorrain was closely identified with the formation of the Scottish Company and probably, therefore, he was also the orginator of this evidence in support of the contention that an exchange was opened in Manchester as early as July 1879.

Announcements made in the Press for the period in question appear however rather opposed to this view.

Extracts from the *Telegraphic Journal and Electrical Review* are as follows :—

September 15th, 1879. Page 293 :

"Telephonic exchanges are now being established in London and other large towns. The Bell Telephone Company have turned their Coleman Street office into a central station for the City; other stations are likely to be opened soon in the Metropolis, and other towns, notably Manchester, are arranging to have exchanges."

September 15th, 1879. Page 306 :

"An attempt is being made to establish a telephonic exchange in Manchester on the American plan. The apparatus to be employed is Bell's receiver and Blake's microphone transmitter."

October 15th, 1879. Page 339 :

"Considerably over fifty subscribers have now been obtained in London to this system of vocal communication . . . over

eighty have been gained in Manchester, and over forty in Liverpool."

In the *Manchester Guardian* for Saturday, September 6th, 1879, an advertisement appeared to the effect that the Lancashire Telephonic Exchange, Ltd., was prepared to receive subscribers and that 75 had already been secured.

The *Manchester City News* for September 13th, 1879, under the heading "A Telephone Exchange for Manchester," stated that "A Telephone Exchange is about to be opened in Faulkner Street."

From the above quotations it seems clear that the exchange at Coleman Street, London, was certainly in operation before September 15th, 1879, and that by October 15th, 1879, exchanges had been opened in Manchester and in Liverpool.

The difficulty which arises in determining the dates of establishment of the first exchanges in various parts of the country will perhaps be appreciated. The question of datal priority is not, however, one of any real importance and will not, therefore, be pursued. Suffice it to say that the period comprised in the last five months of the year 1879 was one of great activity in the establishment of telephone exchange service throughout the country and that so far as the available records show, it is safe to assume that the earliest exchanges to be established in the United Kingdom were those which have been summarised below:—

Town.	Address.	Proprietors.	Probable date of opening.
Glasgow	140 Douglas Street	D. and G. Graham	March 1879
London	36 Coleman Street	The Telephone Co., Ltd.	Aug. 1879
London	Lombard Street	Edison Telephone Co.	Sept. 1879
Manchester	Faulkner Street	Lancashire Telephonic Exchange, Ltd.	Oct. 1879
Liverpool	——	Lancashire Telephonic Exchange, Ltd.	Oct. 1879
Sheffield	Angel Street	Tasker, Sons and Co.	— 1879
Halifax	——	Blakey and Emmott	— 1879
Birmingham	Exchange Ch., New Street	Midland Telephone Co., Ltd.	Dec. 1879
Edinburgh	St. Andrew's Square	Scottish Telephonic Exchange, Ltd.	Oct. 1879
Belfast	2 Castle Ch.	Scottish Telephonic Exchange, Ltd.	— 1880
Sunderland	Arcade Ch., High Street, West	United Telephone Co.	— 1880
Bristol	——	——	Dec. 1879

It will be seen that according to the above scheduled information Glasgow was the first town in the United Kingdom where a telephone exchange was opened. The author has been in communication with Mr. David Graham, from whom the date for Glasgow was obtained, and he confirms it as the nearest date he is able to give.

CHAPTER V

EARLY INTRODUCTION OF TELEPHONES BY THE BRITISH POST OFFICE, 1881–1888

THE introduction and early development of the telephone in this country was watched with interest by the Post Office, but no attempt was made to compete seriously with the pioneer companies. The adoption of the telephone by the Post Office came about more as a natural and gradual process than a deliberate attempt to introduce it forcibly to public notice and to develop it as a commercial project.

The pioneer companies entered into business with the firm idea of inducing the public to adopt the telephone and with fixed intent to secure financial success. The Post Office had no such aspirations.

Moreover, when the practical success of the telephone had been demonstrated and its future seemed assured, it was naturally looked upon by telegraphists and others associated with telegraphy as a possible rival rather than an ally of the then well-established telegraph.

Sir William Preece, who was Engineer-in-Chief to the Post Office when the telephone was invented, displayed great interest in it and in the possibilities which it presented, and did much to promote its progress in this country.

It is, no doubt, true that the Bell patents were offered to and declined by the British Post Office, but such action was in nowise inconsistent with the policy of a Government Department, which has, at all times, to tread very warily when inventors and others display wares of doubtful value and utility, a very common occurrence in the experience of those British Government Departments whose business is concerned with the applications of science and engineering.

At the time of the transfer of the telegraphs to the State in the year 1870, the Post Office acquired, and subsequently continued

to work and develop, in certain busy centres, systems of Wheatstone A B C telegraph circuits, rented by private firms and individuals. In one case, namely, that of Newcastle-on-Tyne, the Universal Private Telegraph Company, the former owners, had introduced a system of switching prior to acquirement of their undertaking by the Post Office.

After the acquisition of the telegraphs, the Post Office introduced similar switching systems in other parts of the country, notably at Swansea, Bradford and Glasgow. These switching systems were introduced in order that one A B C renter might be directly connected through to another, to avoid the necessity for retransmission of the message at the Post Office, and also to reduce the number of instruments and the accommodation requisite for them at the Post Office.

The switching device employed originally consisted of an Umschalter or Universal switch. In its simplest form, the Umschalter switch consisted essentially of two series of insulated brass bars or strips, one set being arranged in front of and at right angles to the other. Holes were drilled through the two bars at each point of crossing. On the insertion of a metallic peg into one of these holes, the two bars crossing at that point were electrically connected together. If telegraph lines were individually connected to one set of bars, and telegraph instruments to the other set, then the switch afforded a very convenient means for connecting any given line to any required instrument, by the insertion of a peg at the point of crossing of the two bars, to which the line and instrument were respectively connected.

An improvement upon this form of switch was one in which the bars comprising one parallel set were utilised as connecting bars only, each of the circuits requiring facilities for inter-communication being connected to a bar of the other set. Two brass pegs were thus necessary to make one connection. A further improvement was an arrangement of half-lapped bars with faces flush, the peg being inserted in holes suitably drilled between the bars.

The A B C telegraph switching devices used at this time by the Post Office were not uniform, but the diagram shown in Fig. 50 may be taken as fairly typical and, so far as can be ascertained, was the arrangement which obtained at Bradford about the year

1875. "Line" and "Earth" reversing switches were necessary at each renter's office.

The manipulative skill which was required in the operation of the Wheatstone A B C telegraph could readily be acquired, without any special training or lengthy experience, and the A B C telegraph fulfilled a want since supplied almost exclusively by the telephone.

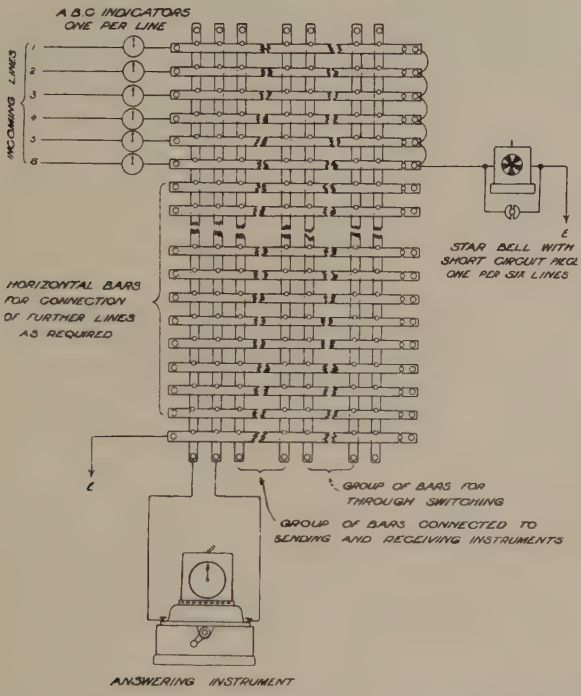

FIG 50.—Diagram of Umschalter or Universal Switch as adapted by British Post Office for providing means of intercommunication between Wheatstone A B C telegraph instruments.

As in the case of other telephone administrations, the telephones first fitted by the Post Office were associated with private wires, and in most cases the telephones replaced or were supplemental to Wheatstone A B C telegraph sets, the existing single wire earth circuit lines being utilised.

The telephone intruments first used by the Post Office were of the type illustrated in Fig. 51. The transmitter was of the Crossley pattern. The activities of Mr. Louis John Crossley, its

inventor, and of Messrs. Blakey and Emmott of Halifax, in introducing telephone working in the neighbourhood of Halifax and Bradford have already received mention in Chapter IV.

Messrs. Holdens, woolcombers, and Messrs. Illingworth, spinners, of Bradford, were interested, at an early date, in the telephone as a means of communication, and made arrangements for telephones to be fitted at their offices and mills, which subsequently replaced the existing A B C telegraphs. At their instigation, telephones were fitted at each end of the lines connecting their town offices with the Post Office, the instruments being supplied

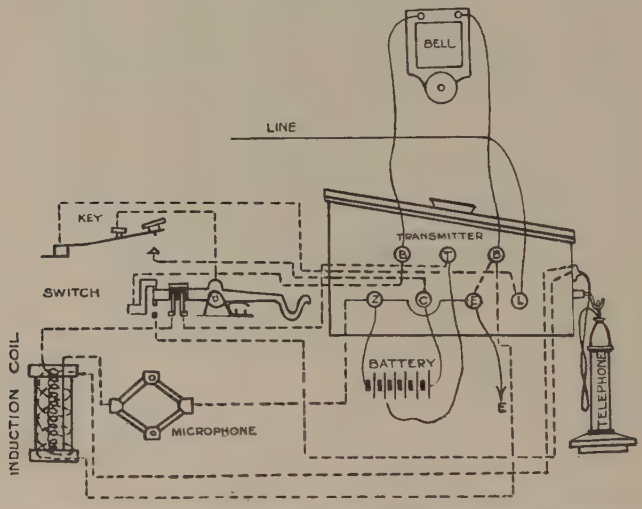

Fig. 51.—Telephone Instrument with Crossley Transmitter as first employed by the British Post Office.

by the firm. In this way telephones were introduced into the Bradford Post Office.

The utility of the telephone, and the advantages it possessed over the A B C telegraph, soon became recognised and the Post Office began to supply telephones on terms similar to those adopted for A B C telegraphs. At first the telephone instruments were fitted in addition to the telegraph sets, switches being provided at the renter's premises, and also at the Post Office, whereby either the A B C set or the telephone instrument might be connected to a single earth circuit line, the idea being that, should the telephone fail, the telegraph might be resorted to. This is an indication that the telephone was not originally accepted

as thoroughly reliable, and to be depended upon to the same extent as the A B C telegraph. The lines, being single, with earth return, worked satisfactorily under ordinary conditions, but sometimes trouble was caused by telegraphic induction which seriously interrupted conversation at busy periods.

The actual telephone switching at Bradford was first carried out by means of an Umschalter switch; the line bars were connected to the jack-springs of the telegraph switchboard—which had replaced one of the Umschalter pattern—thus making the single line available for either telephone or A B C telegraph purposes. It therefore became possible for A B C renters provided with telephones to utilise either the A B C set or the telephone

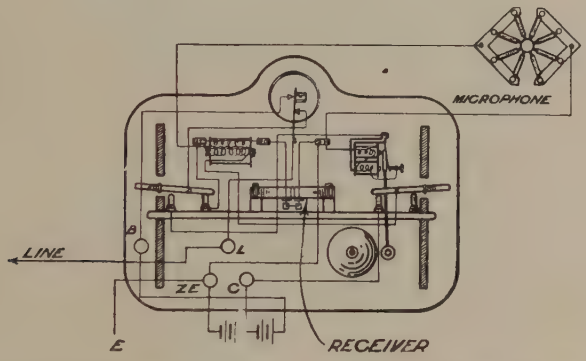

Fig. 52.—Early form of Gower Bell Telephone Instrument used by the British Post Office.

as they desired, the switching operations being performed at the Post Office.

An improved type of instrument was soon introduced, the chief modification being the abolition of the Crossley transmitter in favour of the Gower.

Figs. 52 and 53 illustrate this instrument; with subsequent modifications it was used extensively by the Post Office and by various railway companies. It was known as the Gower Bell Telephone, and was first manufactured by Messrs. Scott and Wollaston, later the Gower Bell Telephone Company. The Consolidated Telephone Construction and Maintenance Company ultimately acquired the Gower Bell Company.

In 1881 the Wheatstone A B C telegraph sets connected to the exchange system at Newcastle-on-Tyne began to be replaced by

telephones and in March 1882 a telephone exchange service was substituted for them.

The Post Office telephone exchange system at Swansea was opened on March 23rd, 1881, the existing A B C telegraphs being replaced by telephones, to be followed on August 31st, 1881, by a Post Office telephone exchange at Cardiff.

During the few years following these dates, numerous Wheatstone A B C telegraph exchange systems situated in various parts of the country were converted to telephone working, an indication of the early appreciation by the Post Office of the merits of the telephone as a means of communication.

Owing to the increasing applications for telephone service and the difficulty of giving a satisfactory intercommunication service with the apparatus and devices available, it soon became apparent that the introduction of considerable improvement in the switching arrangements was necessary. Therefore, in order to provide for the increasing demands of the telephone exchange renters (as they were termed) served by the British Post Office, a universal system of working was designed and adopted throughout the country. The policy of the Post Office did not include active participation in the development of the telephone service generally and therefore, as compared with the private companies, the number of subscribers to be catered for was comparatively small.

The Post Office standard telephone instrument continued to be of the Gower Bell type, an instrument manufactured by the Consolidated Telephone Construction and Maintenance Co., Ltd. The earliest forms of instrument used by the Post Office have already been mentioned and illustrated. The instrument subsequently passed through various stages of development until eventually, on the expiry of the controlling patents in July 1891, a " Universal " instrument was adopted, so called because the general arrangement of the connection was such as to permit of its use under practically every condition of working likely to be met with. The Universal telephone was fitted with two double pole Bell receivers, in place of the Gower receiver with ear tubes, a Gower transmitter, terminals for a call bell, and a relay for the local bell circuit. The bell used with these instruments was of the trembler type. Relays were fitted when the external resistance of the circuit exceeded 200 ohms, or when the instrument

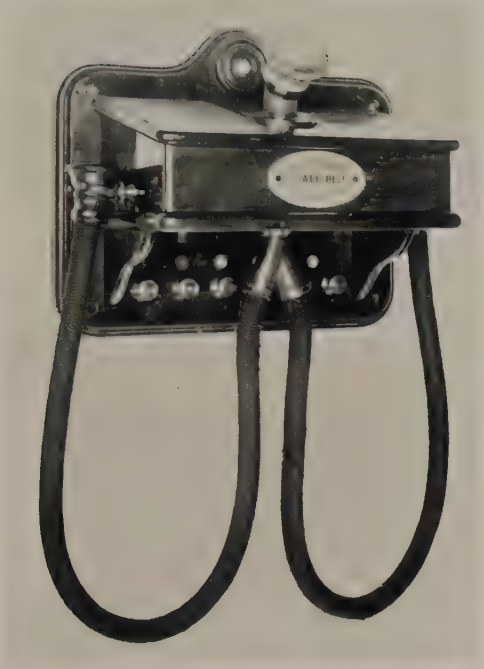

FIG. 53.—The Gower-Bell Telephone Instrument as used by the British Post Office.

(*From a photograph supplied by Mr. H. Wilson.*)

[*To face page* 126.

was to be connected to an exchange. The trembler bell and relay each had a resistance of 100 ohms.

The earliest method of exchange switching universally introduced by the Post Office in association with the Gower Bell

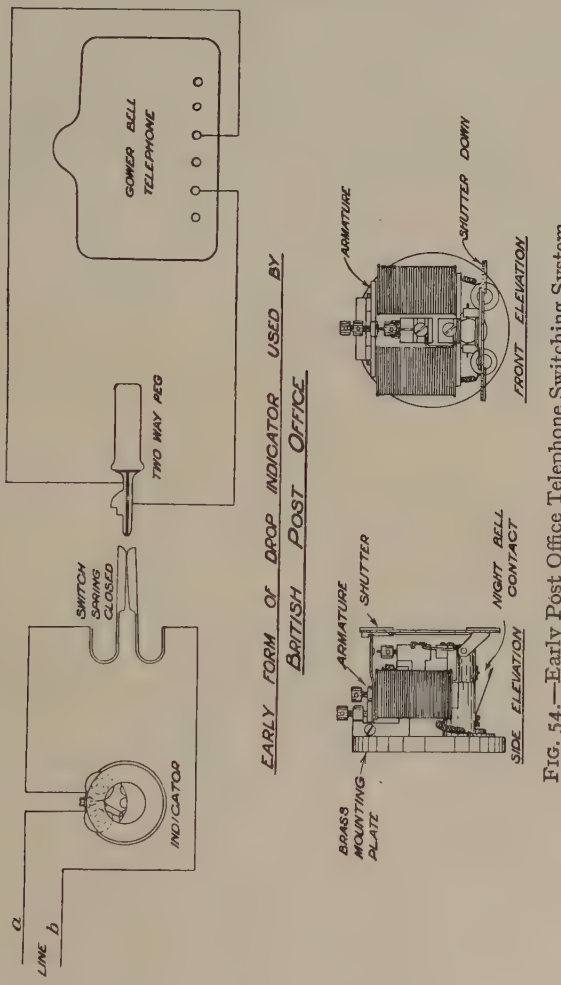

FIG. 54.—Early Post Office Telephone Switching System.

telephone instrument is illustrated in diagram form in Fig. 54. From the outset, metallic circuit systems were installed for exchange working.

The exchange switching device consisted essentially of an uncommon type of switch-spring or jack, an orginal form of

indicator and a two way flexible cord provided with a peg at each end, for connecting purposes. A Gower Bell telephone instrument provided with a flexible cord terminating in a similar peg was at first utilised for operating purposes.

The switch-springs were somewhat similar to those illustrated in detail in Fig. 55, which will be referred to again in connection with a later Post Office system of switching; the chief difference was that the insulating pins were omitted and, therefore, in their normal state, the upper and lower springs were in contact under their own combined pressure, the line circuit being normally completed through them.

Details of the two way peg are given in Fig. 55. It was flat, and provided on its upper face, or " a " side, with a horn-shaped projection of brass; when the peg was inserted between the two switch springs, it fitted between the two portions of the upper spring, suitably divided for the purpose. This was to ensure the peg being inserted in the correct position in relation to the two switch springs.

The indicator, which also is shown in Fig. 55, consisted of an electro-magnet, of horse-shoe type, mounted on a brass base with an armature in the front in the form of a ring of iron, so pivoted that when no current passed through the coils of the electro-magnet it fell forward.

The number of the subscriber appeared upon a small plate of ebonite carried by the ring, and also upon an oblong plate fitted behind the shutter, so that the number was also exhibited when the shutter fell. A small permanent magnetic needle was pivoted between the coils of the electro-magnet, which deflected from the vertical position to right or left according to the direction of the current circulating in the coils. When the shutter fell a local bell contact was closed for the purpose of calling the operator's attention when the switchboard was unattended. The first type of indicator used was of 25 ohms resistance, the coils being connected in series with the " a " line and the upper contact of the switch-spring. The lower spring was directly connected to the return or " b " line, as shown in Fig. 54.

The Gower Bell telephone used in connection with exchange service was in all cases provided with a 200w. relay, and the subscriber's call bell was included in the local circuit.

A distinctive feature of the system was that in the idle state

of the apparatus a current, of the order of some five milliamperes, constantly circulated, from the subscriber's permanent current battery, over the line and through the coils of the indicator, by way of the two switch springs; the subscriber's relay was biassed by means of a spiral spring, so that it was not operated by the permanent current. The shutter of the indicator was, therefore, retained in the normal position, and the direction of the current was such that the needle was permanently deflected to the left. It may be observed by reference to the diagram (Fig. 52) that when the left hand receiver tube of the subscriber's instrument was removed from its rest the permanent current circuit was broken, and the secondary circuit joined up to line, also that removal of the right hand tube closed the microphone circuit, through the primary winding of the induction coil.

On removal of the left hand tube, therefore, the shutter of the exchange indicator was released, and fell forward, and the signal that the subscriber required attention was given. At the same moment, the magnetic needle of the indicator assumed a vertical position, by reason of the demagnetisation of the indicator coils through stoppage of the current. The rule was for the left hand tube to be raised first and when the operator had answered, the subscriber lifted the right hand tube in order to state his requirements. The method of calling the exchange should now be clear. To call a subscriber, the peg connected to the operator's telephone was inserted between the respective switch-springs; the battery of the operator's telephone thus augmented the current passing in the subscriber's line, overcame the bias of the relay, the local bell circuit was closed, and the subscriber's bell rang. The battery at the subscriber's office was so connected that the operator could hear the make and break of the subscriber's bell.

Connection between two subscribers was established by means of the two way connecting cord with plugs at either end.

During conversation between two subscribers, the needles of the respective indicators at the exchange remained in the vertical position. When the subscribers' conversation terminated and the receiver tubes were replaced, the permanent current was restored, and the resultant deflection to the left of the needles of the two indicators was regarded by the operator as the clearing signal; normal conditions were then restored, the shutter of the indicator being restored by hand.

By reason of the permanent current, each subscriber's circuit was constantly subject to an observation test. The hole in the centre of the circular shutter of the indicator enabled the operator to perceive the position of the indicator needle, so that failure of the permanent current in the line circuit or sticking of the indicator shutter when the subscriber called was immediately detected.

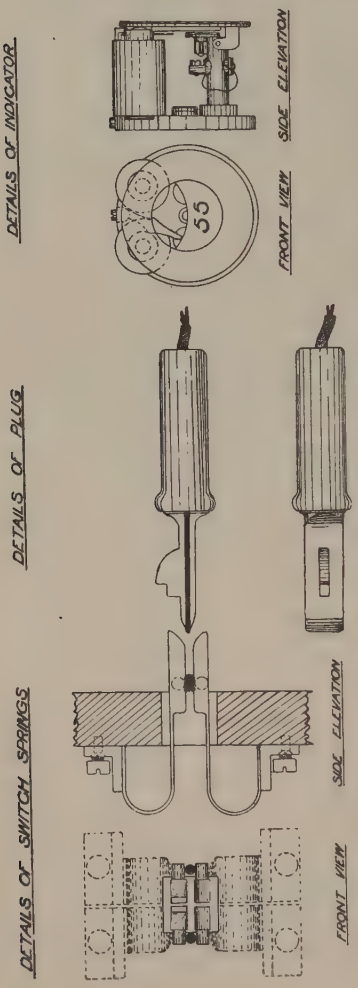

Fig. 55.—Early forms of Switch-spring, Jack and Indicator used by British Post Office.

The system just described remained in force for a period of about three years only, and in the year 1885 an important improvement was introduced. It will, no doubt, have been observed that, during conversation, the coils of the two indicators remained in series with the speaking circuit. It was necessary therefore, in order to minimise the resulting speaking losses to reduce the self-inductive effect of the indicator coils to the lowest possible limit. The improvement referred to was to replace the low resistance series indicators by high resistance indicators joined up in bridge across the line. This necessitated a modification of the switch-spring in order that the circuit might normally be broken there. The new indicators were 1000ω. in resistance, the general form and design being retained.

Besides the reduction in the speaking losses due to the series connected indicator, a further improvement was at the same time effected, inasmuch as the permanent current was reduced by the increased resistance of the indicator.

The self-inductance of the indicator coils was sufficient to preclude a heavy loss in transmission when joined, as they were, in shunt across the line. One form of the new switch-spring is illustrated in detail in Fig. 55. Insulated pins were utilised to

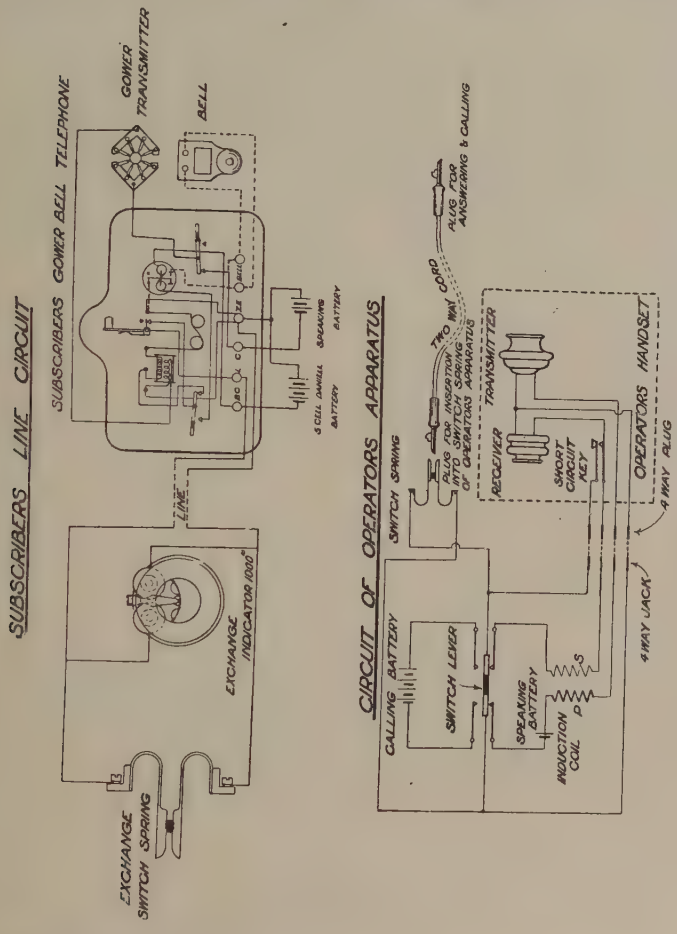

Fig. 56.—Early Post Office Telephone Exchange System.

hold the two springs apart. The same figure shows the peg and indicator. Fig. 56 gives particulars of the modified line circuit.

In Fig. 56, the Gower Bell telephone is shown connected, through the line of the subscriber, to the associated switching apparatus situated at the exchange. The telephone instrument shown was the latest and standard type of instrument introduced in the year 1883.

In the lower portion of Fig. 56 is a diagram of the operator's circuit as modified later on the introduction of the hand micro-telephone. This operator's set consisted essentially of a hand micro-telephone with flexible cord terminating in a four way plug, normally placed in a socket or jack mounted upon a tablet.

The tablet contained the induction coil, ringing and speaking battery terminals, a lever with spring contacts, which served as a ringing and speaking key, and a double switch-spring, similar to that associated with each subscriber's line. One peg of a two way cord, with pegs at either end, was normally kept inserted in the operator's switch-spring. When not in use, the operator's handset was hung upon the lever, which was thus retained in the depressed position and ringing battery was, therefore, connected through the switch-springs to the free peg.

To answer a call, the operator removed the handset from the lever, inserted the free peg into the switch-spring of the calling subscriber, and ascertained his requirements. The peg was then withdrawn and inserted in the switch-spring of the wanted subscriber. On the lever being depressed, the calling battery was put in series with the battery supplying permanent current to the line at the subscriber's station; the augmented current overcame the bias of the subscriber's relay, and thus indirectly rang the bell. On reply of the subscriber, the desired connection was completed by the operator withdrawing the answering plug and connecting the switch-springs of the two subscribers by means of a two way cord fitted at each end with a peg, the operator's apparatus being meanwhile entirely cut out of circuit.

During conversation, the needles of both subscribers' indicators remained in a vertical position. When the subscribers replaced their receivers, the needles were deflected to the left, thus giving to the operator the clearing signal. Normal conditions were then restored.

The arrangement of operators' apparatus was subsequently improved by permanently connecting one end of the loose cord used for answering and calling to terminals mounted on the tablet accommodating the operators' equipment; the switch springs and one peg were abolished.

For large exchanges, *i.e.*, for exchanges at the period in question with more than 100 subscribers, the subscribers' switch-

springs were arranged in groups of 100, and the indicators in two groups of 50 for each group of 100 switch-springs.

Interconnection between subscribers in different groups was afforded by means of transfer circuits; these were simple circuits terminated by switch-springs on the two sections between which interconnecting facilities were required.

FIG. 57.—Early Post Office Telephone Exchange System. Arrangement of Switchboards for exchanges of over 100 lines.

Two operators were thus concerned in one connection between subscribers in different groups, the necessary information regarding the calls being passed by word of mouth.

The illustration in Fig. 57 shows a section of a portion of a switchboard for the accommodation of more than 100 subscribers' lines and the general arrangement of indicators and switch-springs.

As at March 31st, 1892, the Post Office had 35 exchanges giving service to 4691 subscribers' lines besides 691 Government telephone lines.

CHAPTER VI

THE UNITED TELEPHONE CO., LTD., AND THE PROVINCIAL SUBSIDIARY COMPANIES, 1881–1890

THE telephone user and the telephone engineer of to-day are alike indebted to those men who, in the early 'eighties, laid the foundation of what is regarded at the present time as an essential feature of social, commercial and industrial intercourse, viz., the telephone system.

The difficulties which were encountered, and, if the telephone were to be a success, had to be overcome in those early days, can scarcely be appreciated by modern telephone engineers. It is, indeed, a matter for wonder that the telephone flourished as it did or even survived at all. The necessary apparatus was difficult to obtain and in many instances had to be more or less hurriedly made and assembled practically on the spot where it was to be used. Parts of switchboards, such as springs, jacks, indicators, switches, plugs, framework, etc., were for the most part hand-made, machines at that time not being available for mass production of parts. The plant the telephone man is now so familiar with was quite unknown and an entirely new field for the electrical manufacturer was opened up. Standardisation was a dream of the future, and each individual or company designed, constructed and fitted much of its own apparatus on independent lines. There was consequently much variety of apparatus and in the method of operating it.

The early companies were handicapped in many ways; at one time, in particular, financially. More than one company was occasionally without funds with which to pay its staff.

Financiers looked askance at such a doubtful scheme as they considered was comprised in the endeavour to conduct speech between individuals situated miles apart, and therefore capital was at first difficult to obtain.

Before the utility of the telephone was practically demonstrated, it was well-nigh impossible to induce parties to contract

for the use of it, and free services were invariably given by the telephone companies at the outset, in order that a start might be made. Difficulty was experienced in some cases even in securing permission to instal free services. It is significant, however, that very few indeed were withdrawn at the expiration of the term for which they were provided, the subscriber generally electing to pay the rental asked for continuance of the service rather than relinquish it.

Very soon after its formation the United Telephone Company found its hands full with the telephone business, and all the problems and complexities which accompanied it. The business was well established in London, and branches, which were growing more or less successfully, had been opened in some of the more important towns and cities in the provinces. In the provinces, however, but a comparatively small beginning had been made in introducing and developing the telephone exchange service, and, as they held the master patents, it was desirable that suitable steps should be taken to promote their interests generally throughout the country.

As the result of inquiry and mature deliberation, the board of directors came to the conclusion that the introduction and development of the telephone in the provinces would be accomplished most rapidly and successfully by making over to persons locally interested the conduct of the telephone business within the limits of particular districts, conditionally upon the formation of District Companies affiliated to the parent company. Policy was shaped accordingly, and negotiations were commenced for the formation of such subsidiary companies. The general basis of agreement under which this cessor of rights was eventually made was the appropriation to the parent company of equitable amounts of money, or of paid-up shares, in consideration of the goodwill and licence to carry on the business under the several patents. In addition, annual payments in the nature of Royalty upon the telephones actually supplied and used by the subsidiary companies were made, the property in all such telephones resting with the parent company. A royalty of £1 was charged by the United Company for each transmitter and receiver and, in addition, the local company was responsible for payment of the royalty demanded by the Government, as a condition of issue of the requisite licence.

In February 1881 the Provincial Telephone Co., Ltd., was formed with a capital of £75,000. The company did not figure conspicuously in telephone history, and was formed mainly for the purpose of acquiring existing and promoting new telephone companies in various parts of the Kingdom, leaving to the United Telephone Company the task of telephonically developing the London district. Mr. Charles J. Bell, brother to Graham Bell, became general manager for the Provincial Company, which was largely run by Americans. The Provincial Company acquired the businesses of Messrs. Blakey and Emmott of Halifax, Messrs. D. and G. Graham, The Midland Telephone Co., Ltd., of Birmingham, and The Scottish Telephonic Exchange, Ltd.

The first subsidiary company to be formed was floated on March 10th, 1881, with a capital of £600,000 and received the title, the National Telephone Co., Ltd. The territory apportioned to this company was Yorkshire, Nottinghamshire, the province of Ulster and part of Scotland. The National Telephone Company took over the management of the United Telephone Company's concern in Scotland, where the United had previously acquired the Scottish Company.

The Lancashire and Cheshire Telephonic Exchange Co., Ltd., followed on May 21st, 1881, with a capital of £250,000, to operate in Lancashire and Cheshire, the Isle of Man, Westmorland and North Wales.

Mr. Kingsbury, writing in 1882 in his book, "The Telephone in Principle and Practice," said that in the provinces exchanges had been organised by the United Telephone Company or its affiliated companies, the National Telephone Company, or the Lancashire and Cheshire Telephone Company, in the following towns :—Aberdeen, Barrow-in-Furness, Belfast, Birmingham, Blackburn, Bolton, Bradford, Brierley Hill, Bristol, Burnley, Dewsbury, Dublin, Dudley, Dumbarton, Dundee, Edinburgh, Forfar, Garston, Glasgow, Greenock, Halifax, Huddersfield, Kirkcaldy, Leeds, Liverpool, Manchester, Norwich, Nottingham, Paisley, Preston, Stourbridge, Sunderland, Wakefield, Walsall, Wednesbury and Wolverhampton. Arrangements had also been made for opening exchanges in various other places, as well as the suburbs and smaller towns, in the neighbourhood of the above-mentioned.

In the same publication, Mr. Kingsbury also gave a list of the

approximate number of subscribers in telephone connection with exchange systems only in some of the chief cities in the Old and New Worlds, as at the end of December 1881; they were as follow :—

Name of City	Annual Subscription	Number of Subscribers
Chicago	£25	3,300
New York	£30	3,125
Paris	£24	1,400
London	£20	1,338
Manchester	£20	600
Liverpool	£20	525
Glasgow	£20	425

The foregoing information, quoted from Mr. Kingsbury's book, denotes very forcibly how quickly after its invention the telephone had been brought into practical use, and the rapid progress made in such a short period as five years.

On December 13th, 1881, The Northern District Telephone Co., Ltd., appeared with a capital of £100,000 to operate in territory included in the counties of Westmorland, Cumberland, Northumberland and parts of Durham and Scotland.

The Telephone Company of Ireland, Ltd., with a capital of £250,000, to work the whole of Ireland except the portion previously allotted to the National Telephone Company, was formed on May 27th, 1882.

December 17th, 1884, saw the birth of the Western Counties and South Wales Telephone Company, Ltd. This company, with headquarters at Bristol, covered the territory embraced by the western and south-western counties of England, together with the South of Wales. The capital was £400,000.

The remaining portion of the uncovered territory of the country was dealt with on January 29th, 1885, upon the formation of the South of England Telephone Co., Ltd., also with a capital of £400,000.

The Provincial Telephone Co., Ltd., its functions performed, was wound up on September 18th, 1884.

As the subsidiary companies were formed they entered into business in the various localities which they were licenced by the

Government to serve, and immediately took over the control and management of the systems of telephone working in those areas, previously established there by the United Telephone Company. The United Company exercised a large measure of control over their operations, inasmuch as they held all the patent rights and very assiduously saw to it that these rights were respected and upheld. The several companies actively engaged in competition with other parties already engaged in the telephone business, including the Post Office.

So many different concerns were in the field at this time, and such activity prevailed in every direction, that it is almost impossible to give an ordered detailed account of the events which transpired about this period, and the particulars it has been possible to collect must therefore suffice.

By January 1885, therefore, practically the whole of the country was embraced by the seven telephone companies enumerated, and in this way comprehensive arrangements were consummated to develop telephonically the industrial and commercial centres of activity of the United Kingdom.

The National Telephone Co., Ltd.

The National Telephone Company, upon its formation on March 10th, 1881, established headquarters in Glasgow, and acquired control of the business originally instituted in that city by the Bell and Edison companies. The business carried on by Messrs. D. and G. Graham, referred to in Chapter IV, also passed into the hands of the National Company, Messrs. Graham retaining, for a period of three or four years, a contract with the company for the erection and repair of external line plant, but in 1884 or 1885 this contract terminated and the work was undertaken by the company. In 1882 or 1883 an exchange system of A B C telegraphs, worked by the "A B C Telegraph Co.," was absorbed and the subscribers were induced to accept the telephone in lieu of the A B C telegraph instruments. By the year 1884, therefore, the National Telephone Co. had acquired sole control of the telephone exchange service in Glasgow; the subscribers numbered nearly 500, and were served by seven exchanges.

At this time, the Queen Street Exchange, originally established by the Bell Co., was the largest or "Central" exchange; the switching arrangements in vogue there at this period are not

without interest, and have been related for the author by Mr. Paterson. There were, in 1884, approximately 300 subscribers working to the Glasgow Queen Street Exchange, and they were provided for by a sliding spring-peg switchboard, specially arranged to accommodate the number of subscribers mentioned, and manufactured by the Railway and Electric Appliances Company, of Polmadie, Glasgow. The principle of this switching device was precisely the same as that employed in the switchboards of similar design in use at Sheffield, Sunderland and numerous other places in the same period. The Williams sliding spring-peg switchboard is described in Chapter IV, but in view of the much larger number of subscribers accommodated by the Glasgow board, and of the fact that it was the largest switchboard of its type in use in this country at any time, some details of its design and arrangement, and the method of operating adopted, will not be inappropriate. An illustration of a section of the switchboard in question is given on page 136 of Aitken's "Manual of the Telephone."

There were seven subscribers' sections each with a capacity for 50 subscribers and accommodating two operators, also a trunk section *en suite* with the subscribers' sections, and a junction section in a separate room. A cross-section of the arrangement, largely diagrammatic, and not to scale, from a drawing prepared by Mr. Paterson, is given in Fig. 58. The horizontal rods were of semicircular section, and, besides the earth bar and two speaking bars per section—one of the latter for each operator—there were two bars for communicating with the trunk section, five for the junction section, five, lettered A in the sketch, for connections confined to the home section, and six sets of five rods each coded B, C, D, E, F, and G for communications to and from the other six sections which were similarly identified.

From the test-board, each subscriber's line was extended by means of a gutta percha insulated wire direct to its respective indicator, from which connection was made to a vertical bar of rectangular section. There was a vertical bar for each subscriber's line, and one connected to the operator's instrument in addition to the horizontal rod. Each vertical bar was fitted with a sliding spring-peg similar to that described for the Sunderland board in Chapter IV, and by traversing the vertical bar

this peg might be brought into contact with any one of the horizontal rods. Normally, each peg made contact with the lowermost, or earth-connected rod, and the subscriber was thus enabled to call the exchange. When an indicator shutter fell the operator drew the peg towards her in order to disengage it

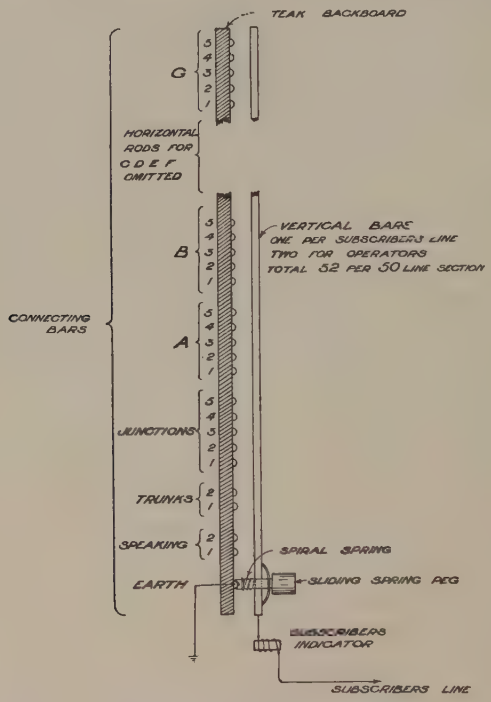

Fig. 58.—Diagram of Sliding Spring-peg Switchboard as arranged at Glasgow, 1885.

from the earthed bar, against which it was held firmly by compression of a spiral spring and, moving it upwards to her horizontal speaking rod, answered the call. The left hand operator of each section used rod number 1, and the right hand operator rod number 2. If the line of the subscriber to be called was terminated on the same section, the sliding spring-peg was lifted up to engage with one of the local connection bars. On the A section these bars were coded "A," on the B section "B," and so on. The spring-peg associated with the vertical bar corresponding to the number of the subscriber wanted was then raised from its normal position against the earthed rod to the operator's

speaking rod, the ringing key depressed and the subscriber called. On receiving a reply, the spring-peg was again moved, until it engaged with the rod to which the calling subscriber's line had previously been connected and the two subscribers were then in communication. As the lines were all earth return, transmission took place with both indicators in series in the circuit, and they were thus available for clearing purposes. The operator was able to listen in by using the spring-peg to connect her vertical speaking bar with the horizontal rod used for completing the connection.

Connection between subscribers whose lines terminated on different sections was established by means of the groups of horizontal rods connected between the several sections, and at non-busy periods, when the chief operator was not present, the operators expressed their requirements one to another by word of mouth as occasion arose, but during the busy hours of the day boys were employed as messengers. On receipt of a call for a subscriber whose line terminated at another section, the operator entered upon a ticket or docket, on which was printed the code letter of the originating section, the number wanted and the number of the horizontal rod between the home and distant sections she selected for use : she then attracted the attention of the messenger, by waving behind her the completed docket. It was the messenger's duty to convey the docket to the operator situated at the section where the line of the subscriber whose number it bore was terminated; the connection desired was then made by the operator raising the spring-peg on the vertical bar corresponding to the required number, to the horizontal rod specified on the ticket. The operator at the originating section then rang the subscriber wanted, and when his attention had been secured, completed the connection by means of the spring-peg associated with the calling subscriber's circuit. Junction and trunk calls were established in a similar manner and both incoming and outgoing traffic was dealt with at the same junction and trunk positions.

In addition to the switchboard described, there was also at Queen Street, in 1884, a small exchange worked by the Law Call-wire system. Subscribers were rung by battery on a single stroke bell. The switch-hook of the subscriber's instrument had three positions; the central was the normal position for receiving

a call; when the switch-hook was moved to the left, the instrument was joined to the call wire for calling purposes; and with the switch-hook to the right the subscriber's speaking set was joined to the exchange line for speaking.

In 1884, the telephone directory contained no entry of the name of the exchange to which subscribers were connected; only one series of subscribers' numbers for the whole area was used. This practice was by no means uncommon at this period, even London being no exception. Groups of numbers were allotted to each exchange, the arrangement in Glasgow being as below.

Name of Exchange.	Equipped Capacity.	Approx. No. of working subscribers.	Allotted Nos. commencing at
Douglas St.	100	80	1
Queen Street.	400	300	501
Royal	50	25	1001
Louth	50	7	1501
Hillhead	50	30	2001
Bridgeton	50	20	2501
Hope Street	50	30	3001
Total	750	492	—

On October 14th, 1881, the Dundee and District Telephonic Co., Ltd., secured from the Postmaster-General a licence to carry on telephone business in the locality denoted by the title of the firm and from the date of the formation of the company until 1885 acute competition occurred between the National and Dundee companies.

The National Telephone Company's rate, at that time in accord with the rates generally charged by the companies operating under the licence of the United Company, was £20. The Dundee and District Company adopted a competitive rate of £10. The National Company immediately reduced their rate to £5 and their opponents responded by a reduction to £5 10*s*.

The Dundee and District Company, with offices at 104 Commercial Street, served as many as 330 subscribers by October 1884. The National Company adopted the Mann Call-wire System and in June 1885 served 915 subscribers. An offer made

by the National Telephone Company to purchase the Dundee Company's system was finally accepted in June 1885, the purchase price being £8500, an obligation being placed upon the company to charge a rate of not more than £10.

Chapter IV relates how the telephone was first instituted in Sheffield by Messrs. Tasker, Sons and Company. This firm gained the reputation of being one of the most successful private telephone ventures in the kingdom. They had the privilege of erecting private telephone exchanges for Her Majesty Queen Victoria at Balmoral and at Windsor Castle, and the firm's exchange at Sheffield was honoured by a visit paid by members of the British Association. In 1886 there were as many as 343 exchange lines connected to the Sheffield Company's system.

In 1883, the National Telephone Company made an attempt to acquire by purchase the well-established system worked by Messrs. Tasker in Sheffield, but the proposition was very firmly negatived and as a consequence a rival telephone system was started by the National Telephone Company, a competitive exchange being opened in Change Alley. For five years, commercial warfare was strenuously waged between the rival parties, and acute and bitter competition ensued. The attitude and conduct of one company towards another, and the methods which were adopted to secure the premier position, were in many cases more amusing than polite. It is related how, on one occasion, the rival companies secured wayleave for the erection of a large pole in the sole available position on one property. One of the companies had made all preparations for the erection of their pole on the morrow, and had actually completed the excavation of the hole for reception of the pole. What was the surprise of the workmen, when they appeared with the pole on the following morning, to find that their more enterprising rivals were before them, and had already erected a pole in the hole they had gratuitously dug for them on the day previous.

Few firms and individuals manufactured and attempted to sell telephones, apart from any arrangement made with the United Telephone Company, without being, at one time or another, brought into the Law Courts by the company in defence of its patent rights. Messrs. Tasker, Sons and Company were no exception, and on June 8th, 1888, they appeared in the Chancery

Division of the High Court of Justice, before Mr. Justice Fry, as defendants in a case brought against them by the United Company. The company claimed an interim injunction to restrain the defendants from infringing their patents for telephone transmitters and receivers. Messrs. Tasker admitted that they were using telephones which infringed the plaintiff company's patent dated 1876, but attempted to justify their action by argument to the effect that they established their telephone exchange at Sheffield at the instance of, and by agreement with, the plaintiffs or their predecessors in title, and accused them of breach of contract in refusing to supply them with further telephones. In these circumstances, Messrs. Tasker admitted that, for the preservation of their business, they had made and used telephones which were infringements. An injunction was granted with the stipulation that the plaintiffs were to supply to the defendants, upon usual terms as to costs, but otherwise by way of loan or sale, or letting at their pleasure, so many telephones as the order precluded defendants from using.

Disagreement subsequently arose between the opposing parties as to the number of instruments in dispute, the defendants asking for 44 instruments in excess of the 52 which, apparently by order of the court, they were entitled to demand from the United Company, and the case was again brought before the court for settlement. Mr. Justice Kay presided over the proceedings on July 6th, 1888, and eventually ruled that the plaintiffs might have the choice, either of extending their undertaking to the 44 instruments in question, or withdrawing from their undertaking with the injunction previously declared discontinued. The matter was carried to appeal and on July 18th, 1888, was heard before Lords Justices Cotton, Fry and Lopes, the appeal being allowed; the judgment was that Mr. Justice Kay should have been satisfied, on the evidence taken, that the undertaking given by the plaintiffs applied only to the 52 telephones.

There was no intercommunication between the two Sheffield systems, and the improved plant, stronger position and greater resources of the National Company ultimately prevailed and compelled the Sheffield company to agree to the purchase of the telephone portion of its business, which was taken over by the National Company in 1888.

The two exchanges were soon after closed, and a new magneto

FIG. 59.—Complete Set of National Telephone Company's Call Office Stamps.

(From a collection in the author's possession.)

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exchange with modern multiple switchboard was opened in a new building, acquired from and built partly for the purpose by the Sheffield Company, in Commercial Street.

The National Telephone Company found, in Belfast, two companies in active competition. The United Company were in dispute with the Scottish Telephonic Exchange, Ltd., over their patent rights, claiming that the latter company were infringing. The National Telephone Company took over the business of the United Company, and ultimately bought out the Scottish company. The two rival exchanges were amalgamated at 3 High Street in 1890.

An experiment made by the National Telephone Company, in December 1884, will be of special interest to philatelists. In order to obviate the necessity for payments to call office attendants in cash, a series of stamps was issued for sale to and use by subscribers and members of the public, and when making use of the telephone at a public call office they were expected to affix a stamp of the correct value to a form kept for the purpose by the attendant.

The stamps were issued in the denominations given below :—

1*d.* Black.
3*d.* Pale red.
4*d.* Ultramarine.
6*d.* Bronze green.
1*s.* Brown.

The complete set is illustrated in Fig. 59.

The several values corresponded with certain of the company's fixed scale of charges, based upon the distance between the points of communication. Each stamp bore a three-quarter face portrait of Colonel Robert Raynsford Jackson, chairman of the board of directors of the company at the time of issue of the stamps. The stamps were at one time much used in Scotland, but in view of the possibility of their confusion with, and use by the public as, postage stamps, they were withdrawn in 1891 at the request of the Postmaster-General.

The Lancashire and Cheshire Telephonic Exchange Co., Ltd.

The Lancashire and Cheshire Telephonic Exchange Co., Ltd., commenced operations in Liverpool and Manchester by absorbing

the Lancashire Telephonic Exchange, Ltd., who had already done pioneer work in that locality. The old Edison Telephone Company's plant was acquired, as was also, in 1881, the telephone business of David Moseley and Sons, of Manchester. In 1882, the newly-formed Lancashire Company commenced operations in North Wales, and in the same year opened seven new exchanges there. The first exchange in Chester was opened early in 1882, and was situated at the offices of Mr. W. E. Brown, 3 Newgate Street, where an Edison switchboard similar to that diagrammatically illustrated in Fig. 11 was installed. In 1882, there were in Liverpool about 450 single-wire subscribers' circuits.

In December 1886 the competition carried on for about five years in Preston, Lancashire, between the Lancashire and Cheshire Telephonic Exchange Company and Messrs. Sharples and Company (referred to in Chapter IV) was brought to an end by the purchase of Messrs. Sharples' undertaking. The combined systems at that time accommodated approximately 500 subscribers.

The Northern District Telephone Co., Ltd.

At the time of formation of the Northern District Telephone Co., Ltd., the United Company had already commenced operations first in Sunderland and later in Newcastle-on-Tyne.

The Northern District Company had for its only competitor the Post Office, and was the only one of the six provincial telephone companies to face the difficulties of competition with a department well equipped for the work in prospect, and with the advantages it possessed in having at its command suitable buildings in which to establish exchanges, and existing line plant provided for telegraph purposes, which could be made use of in the erection of subscribers' circuits. It has already been observed that an exchange was started in Sunderland as early as 1880, but no exchange had as yet been opened in Newcastle. A difficulty was met by the Northern Company in connection with the acquisition of the requisite licence to open an exchange in Newcastle-on-Tyne. Apparently the telephone company acted in open defiance of the Government and established an exchange without its sanction; the consequent action of the Post Office was such as to compel the company to close the exchange, already giving service to a small number of sub-

scribers. The service ceased on July 25th, 1882, but was resumed in May of the following year.

The Bell, Edison and Blake patents, the master telephone patents, were at this time vested in the United Telephone Company, who were determined that the Post Office should be precluded as far as possible from obtaining instruments manufactured under these patents. The Post Office, however, when issuing to the Northern District Telephone Company the licence required for instituting telephone service in Newcastle-on-Tyne, inserted a clause in the indenture, dated May 14th, 1883, making it incumbent upon the company to sell or procure to be sold, and deliver or procure to be delivered to the Postmaster-General, free from restrictions or conditions, telephone and other telegraphic apparatus of the like kind used by the company as part of or in connection with their telephone exchange undertaking. There was also a further clause, to the effect that the company should grant, or procure to be granted to the Postmaster-General, such licences as he should require, entitling him, or companies on his behalf, to manufacture telephones, and other telegraphic apparatus, in accordance with the specification of any Letters Patent relating thereto, belonging to or subject to the deposition, or under the control of, the company, in consideration of the payment, by the Postmaster-General, of the royalties. The Northern District Company did not, however, control the patents to which these clauses referred. Nevertheless, the terms specified were accepted in order to procure the required licence.

The Post Office also had decided to establish a competitive telephone service in Newcastle, and the city was energetically canvassed. An exchange situated at the Head Post Office was opened on October 1st, 1882.

Mr. A. W. Heaviside, the Superintending Engineer to the Post Office Northern Engineering District, held very decided views regarding the telephone service, and was particularly active in engaging the Northern Company in competition. Mr. C. B. Clay, general manager for the Northern District Company, was equally assiduous in meeting the aggressor, and very lively passages resulted. Relations between the rival administrations were very much strained, and the struggle was both strenuous and protracted.

Mr. A. W. Heaviside, assisted by his staff, ultimately evolved

a system of telephone working, described elsewhere, which he proceeded to develop, but the system was not extended to other parts of the country.

The line circuits of the Post Office were metallic loops and therefore conformed to the universal Post Office practice. They were wholly underground within the City of Newcastle, and were composed of gutta percha insulated wires drawn into cast iron pipes.

Contrary to the general practice of the private telephone administrations, the Northern District Company also adopted a system of metallic line circuits, a practice followed by that company in other places with the exception of Sunderland, where a single line system had been established formerly. This policy, advocated by Mr. Clay, the general manager, proved, in later years, to have been the right one, and was the means of avoiding the heavy expense and disturbance of plant otherwise entailed in doubling the circuits at a subsequent date.

The company's line system at Newcastle-on-Tyne was, like that of the Post Office, also almost wholly underground, single gutta percha insulated wires being first used; later four wire or "quad" gutta percha cables were introduced. Newcastle-on-Tyne was the first place in the country to adopt generally underground distribution, and this city has not, therefore, been subjected to the unsightliness which, æsthetes allege, is such an undesirable feature of the overhead system. It was not entirely at the option of the company that an expensive system of underground distribution was adopted in Newcastle-on-Tyne. The city authorities, together with many other bodies, had a well-rooted antipathy to the idea of an overhead system, and they brought such pressure to bear upon the company that the necessary line plant had either to be installed underground or the company's programme for opening telephone service abandoned or seriously curtailed.

The Northern District Company's original exchange at Newcastle-on-Tyne was situated at 13 Exchange Buildings, Quayside, and the Post Office exchange was accommodated at the Head Post Office. In 1888, the Northern District Company's subscribers in Newcastle-on-Tyne numbered 59, which increased to approximately 300 in 1890; those of the Post Office were about 500. An illustration believed to be of the Northern District

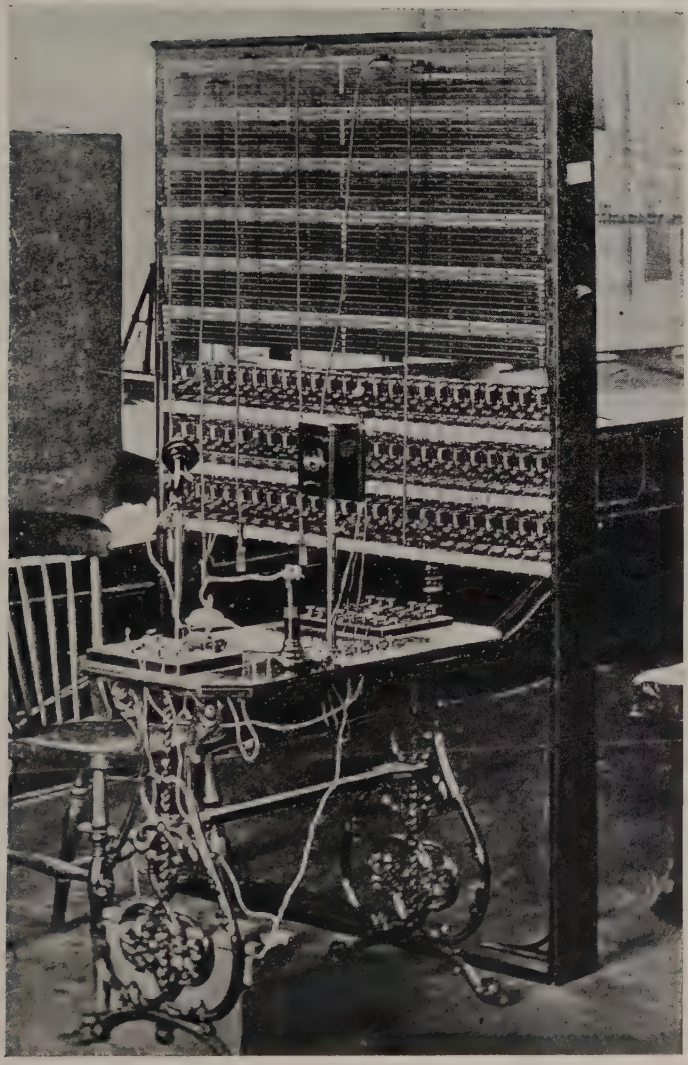

FIG. 60.—An early Switchboard of the Slipper-jack Type, supposed to be Newcastle-on-Tyne, 1882.

(From a photograph lent by Mr. C. B. Clay.)

[*To face page* 148.

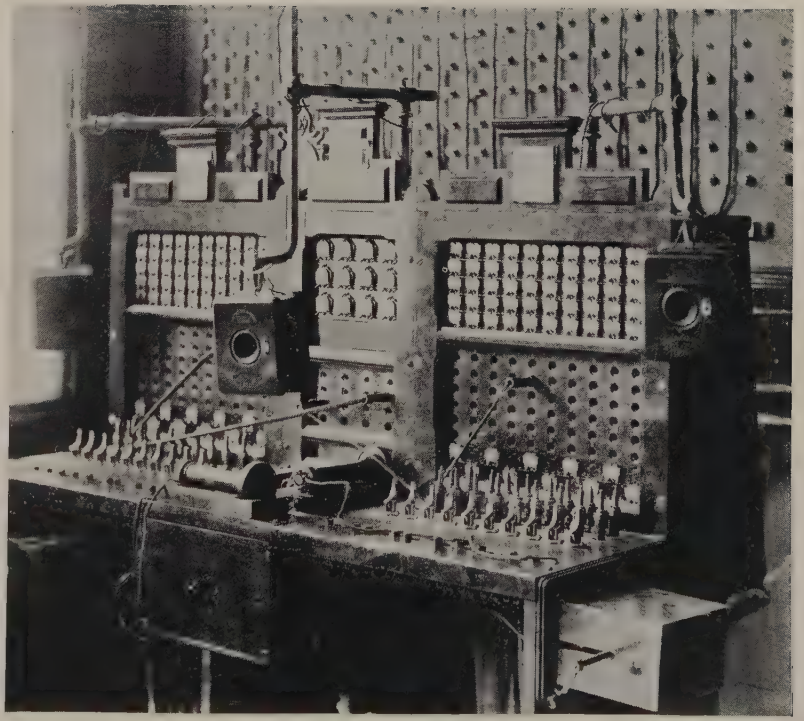

FIG. 61.—The Northern District Telephone Company's Switchboard at Exchange Place, Middlesbrough.

(From a photograph by Mr. F. Barr.)

[*To face page* 149.

Telephone Company's first switchboard at Newcastle-on-Tyne, from a photograph kindly supplied by Mr. C. B. Clay, appears in Fig. 60.

The original switchboard at Newcastle-on-Tyne was similar to the one described in Chapter II, employed by the Telephone Co., Ltd., at 36 Coleman Street, London, E.C., but consisted of one connecting panel and one operating table only, as appears in the illustration. This type of switchboard, the connections of which are dealt with in Chapter II, was originally designed for earth circuit working only, and therefore modifications had to be made in order to admit of its accommodating the metallic circuit lines at Newcastle-on-Tyne. The normal earth connection was removed from the sole or plate of the slipper, and the subscriber's return wire connected to it instead. The connecting cords contained two independent conductors connected to a plug with two contacts instead of one, one on either side, so that when inserted into the slipper the two contacts made connection respectively with the spring and the plate of the slipper.

In the Northern District in 1885 the Post Office had exchanges at Newcastle, Sunderland, South Shields, North Shields, Tyne Dock, Hartlepool, Stockton and Middlesbrough.

Middlesbrough was one of the towns in which the Northern District Telephone Company was the first to introduce the telephone for purposes of intercommunication. An exchange was opened in November 1885 with 17 subscribers and by December 1886 there were 56.

In Fig. 61 is shown the Northern District Telephone Company's switchboard at Middlesbrough; it may be taken as typical of many exchanges of similar size existing at about that time. The centre panel of this switchboard contained the jacks and indicators associated with the trunk circuits. The panels on either side each accommodated indicators and jacks for 50 subscribers; the total fitted capacity was 100 subscribers and 12 trunk lines. There were ten pairs of cords, speaking keys, ringing keys and ring-off indicators for each position. Two cradle switches for reception of the two operators' receivers when not in use cut out the battery and were a feature of this switchboard. The rows of terminals seen at the rear of the board connected together the outside lines and the switchboard wires, and constituted a test-board and a main distribution board.

The operators' transmitters were of the Blake type and were mounted in wooden cases. The method of suspension is distinctly shown in the photograph. This switchboard was replaced by a multiple board in July 1889.

The Telephone Company of Ireland, Ltd.

The Telephone Co. of Ireland, Ltd., took over the control and management of the business in Ireland previously in the hands of the United Telephone Company, with the exception of that apportioned to the National Company.

The Western Counties and South Wales Telephone Co., Ltd.

The Western Counties and South Wales Telephone Co., Ltd., acquired the interests and control of the plant previously vested in the United Telephone Company in the area they were licenced to operate.

The South of England Telephone Co., Ltd.

The South of England Telephone Co., Ltd., on its formation proceeded to develop the territory allotted to them and as a commencement took charge of the business previously built up in that area by the United Telephone Company.

In 1883, the rating assessors were led to look upon the plant of the telephone companies, situated upon properties other than their own, as a possible source of additional revenue, and in June of that year the overseers of the poor for Manchester made an assessment, rating the Lancashire and Cheshire Telephonic Exchange Company, as occupiers of the offices in Falconer Street, Manchester, and of land, telephone posts and wires in the township, at a gross rental of £2400 and a rateable value of £2000. The company recognised their liability with respect to land and premises, but declined to do so in regard to the poles and wires, claiming that the latter did not create such an occupation by the company as to be rateable, and the matter was referred to the Divisional Court of the Queen's Bench for settlement. The case was heard on July 3rd, 1884, before Mr. Justice Mathew and Mr. Justice Day, who decided the question in favour of the rating authorities. The case was eventually carried to

appeal, and in December 1884 was considered by the Master of the Rolls and Lord Justice Lindley, who dismissed the appeal with costs. Notice of appeal to the House of Lords was given, but the matter does not appear to have been taken any further.

In the telephone business, the administration is necessarily dependent upon private property owners and public authorities to furnish means for the accommodation of their line plant, and the early telephone companies were soon involved in troubles and difficulties in securing and maintaining, upon reasonable terms, wayleave for their overhead and underground lines.

The position of the early telegraph companies, in respect of ability to make use of public property, for the accommodation of their lines was an enviable one in comparison with that in which the telephone companies found themselves at an early date in their activities. The first telegraph companies were empowered to conduct telegraph business, and to lay lines along the public highways, by special Acts of Parliament, but in 1863, consequent upon the growth of the telegraph business under the management of the private companies, a general Act, known as the Telegraph Act, 1863, was passed. This Act defined the powers conferred upon companies authorised by special Act of Parliament, to construct and maintain telegraphs, and the conditions under which those companies might break up thoroughfares for the purpose of laying telegraphs; it also imposed certain obligations and responsibilities in the exercise of the privileges which it bestowed.

In passing, it may be mentioned that, in 1870, when the telegraphs passed into the hands of the State, the powers conferred by this Act were vested in the Postmaster-General. With this precedent, the private telephone companies probably felt reasonably assured that similar powers in respect of telephone plant would be forthcoming upon application being made in the proper quarter. Consequently, in 1884, in order to strengthen their position in the matter of wayleaves, and to attain some measure of independence of the goodwill of the public, the United Telephone Company sought Parliamentary powers for the installation of underground and overhead plant on public and private property. Owing to the opposition encountered, the Bill had ultimately to be withdrawn, and the United Company, and the companies operating under their licence, were left to their own resources,

and had to do the best they were able with both public authorities and private property owners in regard to the numerous wayleaves they required throughout the country, unaided by any statutory powers.

A second Bill for a similar purpose was presented in Parliament by the United Company in 1885; a Select Committee was appointed to consider and report upon the matter, and the Bill was withdrawn. A report, issued on May 12th, 1885, was favourable towards a policy of investing the Post Office and telephone companies with certain powers, but the report, for some reasons not stated, was never acted upon. In view of the favourable findings of the Select Committee the United Telephone Company presented in Parliament a further Bill for the same object in 1888. It was, however, withdrawn owing to the hostility it encountered.

An important action in connection with the erection of overhead wires across public thoroughfares was brought against the United Telephone Company on May 8th, 1884, by the Board of Works for the District of Wandsworth, when an injunction was applied for to restrain the United Telephone Company from retaining or placing any wires over, along or across any street under its control without its consent. The injunction was actually granted, but was ultimately reversed in the Court of Appeal. This decision was of no small importance to the private telephone administrations, and settled the question of the right of the telephone companies to erect and maintain wires over public thoroughfares.

Had not the matter been settled in the company's favour, there is no doubt that a great handicap would have been imposed upon their operations and further development by them of the telephone service retarded.

Up to this time the several companies licenced to carry on telephone business in local areas were not empowered, under the licences they held, to arrange for intercommunication between towns in the various areas defined. As the established local service expanded and the number of subscribers increased, the need for intercommunication between distant towns became apparent, and steps were taken to obtain permission to institute such a service. Arrangements were ultimately made and the conditions agreed upon. Fuller treatment is accorded the history of Long Distance Communication in Chapter XVIII.

Mechanical Telephones.

Mention has already been made of the fact that the developments which immediately followed the invention of the telephone by Graham Bell revived interest in the so-called string telephone. This device depended for its action upon the progression of mechanical vibration along a string imparted by sounds impinging upon a diaphragm to the centre of which the string was attached. Numerous experiments were conducted with the object of ascertaining the possibilities of the transmission of sound by mechanical means, and amongst the many attempts made to circumvent the master patents of the electric telephone were some dependent upon the mechanical principle. In due course, several different forms of instrument were evolved and they gave more or less satisfactory results over short distances. They were placed on the market in competition with the electric telephone, and, apart from other considerations, they certainly appeared to possess the advantage that they did not in any way infringe the Bell and Edison patents.

In 1889, Messrs. Woodhouse and Rawson, of 11 Queen Victoria Street, London, E.C., advertised "Mechanical Telephones suitable for short distances." The advertisement stated that, by long use in the States, they had proved themselves the best in the market, and that they did not infringe any of the United Telephone Company's patents.

Mr. Charles H. Ellison, telegraph superintendent of the North Eastern Railway Company, has kindly furnished the author with interesting information relative to a mechanical telephone at one time employed by that company, together with a drawing, reproduced in Fig. 62, of an instrument fortunately preserved at York.

The particular type of instrument used by the North Eastern Railway Company was known as the "Atlas" telephone; it was made by Mr. James Fraser, of Leeds. The appliance consisted of a wooden base or backboard supporting, by means of three metal pillars, a cylindrical sound chamber and a diaphragm of red sheet fibre; the communicating wire was attached to the centre of the diaphragm and securely held in position by a metal washer. The "line" wire was of 3/22 B.W.G. bare steel. The drawing should make clear the construction of the instrument.

Attention was summoned to the distant instrument by striking the metal washer with a pocket knife or other convenient article.

The company had three or four sets, each consisting of two instruments, in use in the neighbourhood of Newcastle-on-Tyne, Tyne Dock, Blaydon and Sunderland, within the period 1888 to 1892, and they were operated up to a distance of about 500 yards.

In the erection of the line considerable difficulty was experienced in turning corners and in leading the wire into offices. It was found that an accumulation of rime or snow upon the wire effectually stopped communication, also that the line wire required frequent renewal.

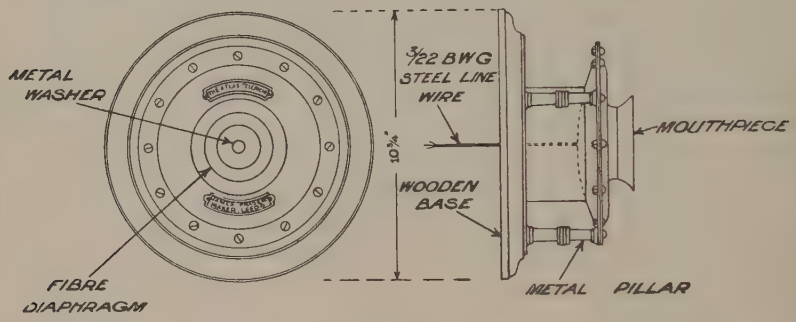

Fig. 62.—"Atlas" Mechanical Telephone used by the North-Eastern Railway Company.

(From a drawing supplied by Mr. C. H. Ellison.)

In the November and December issues of *The Telephone* for 1889 particulars were given of the "Pulsion Telephone," another instrument based on a purely mechanical principle. The device comprised a copper disc or diaphragm associated with a series of short spiral wires, of various thicknesses, so arranged as to "catch the sound waves and condense them on the disc," and a steel connecting wire. The transmitter also acted as receiver. It was observed that the device had been in operation in the United States for many months, and that, as tested on a line of about a third of a mile in length, the sounds were clearer than those transmitted by the most perfect and best known telephones in use at that time. If laid under water or along the ground, the sound continued to be transmitted. Local syndicates were at that time in course of promotion in the principal towns to

bring the Pulsion telephone into common use. One had already been started in Glasgow at the date named. It was intended to confine the use of the device to private purposes. The instrument was stated to be so sensitive that, on listening closely, the patter of rain on the wire was audible. An electric bell was provided for signalling purposes, but was not a necessary adjunct, as by tapping on the instrument the knocks were repeated in a manner which immediately called for attention. As a receiver was not needed, nothing had to be held to the ear, and conversation was possible a yard away from the instrument. An india-rubber tube could be attached, to permit of speech being conducted whilst the correspondent was seated at a desk.

On December 4th, 1889, according to *The Telephone*, some experiments were made with the Pulsion telephone between Finchley Road station and the Welsh Harp, a distance of over three miles, the necessary wire being supported on the ordinary telegraph poles. Conversation was carried on with ease. A feature claimed for the invention was that by placing a walking stick, umbrella or felt hat against the wire messages could be received with ease. A felt hat placed against the wire near Child's Hill station enabled conversation to be conducted with Hendon, messages being audible several feet away. It was not essential that the wire should be taut, and transmission was satisfactory even when the wire was twisted round the branches of trees. It was stated that a company was in process of formation and that the patents had been pronounced to be valid and of a novel character.

Mr. J. Sayers, telegraph superintendent of the Midland Railway Company, has kindly caused inquiries to be made regarding these trials, and confirms that experiments with a mechanical telephone were conducted on that railway at the places named, but as the dates quoted are at variance it must be assumed either that experiments were conducted at different times, or were extended over a somewhat lengthy period.

Mr. Sayers says that the Midland Railway Company were not concerned with the device, but that the matter originated with a request from Sir William Preece (then Mr. W. H. Preece) to Mr. W. E. Langdon, at that time telegraph superintendent of the Midland Railway Company, to afford facilities for the inventors to carry out experiments along the railway company's

line. The trial was carried out by the inventor at his own expense. Mr. Sayers furnishes a copy of a report by the late Mr. George Nichol, one of the company's inspectors, dated July 2nd, 1889, where it was stated that a 2-strand steel wire line had been erected from West End to near Child's Hill and a short line of single copper wire from West End to the telegraph office near by. The wire was slack and for the sake of the experiment lay for some part of the distance along the ground. The line

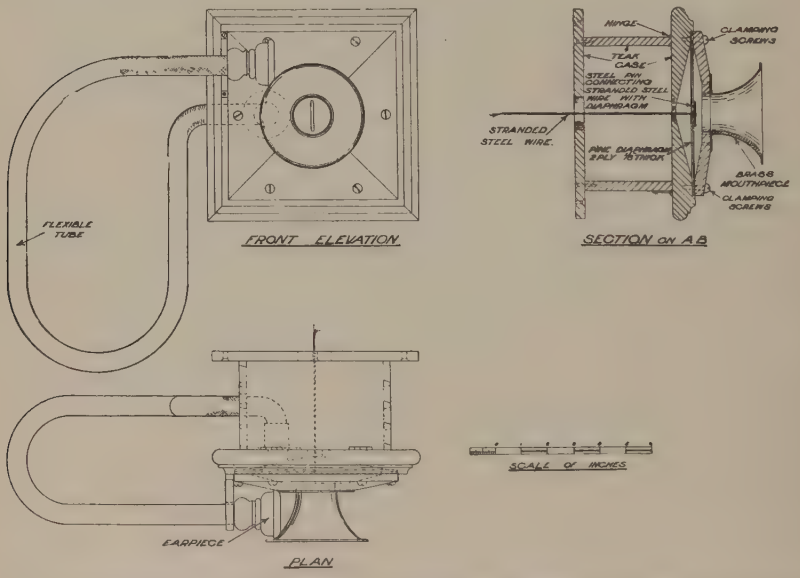

FIG. 63.—Mechanical Telephone used by the Great Eastern Railway Company.
(From particulars supplied by Mr. H. W. Thornton.)

worked well, although the voice was reproduced in a peculiarly harsh, nasal tone.

Some further particulars regarding the use made of mechanical telephones in this country in the period immediately preceding the expiration of the telephone patents have been kindly supplied by Mr. H. W. Thornton, general manager of the Great Eastern Railway Company, who also placed at the service of the author an actual instrument at one time in use by the Great Eastern Railway Company, from which the drawing in Fig. 63 has been prepared. The drawing is self-explanatory and detailed description is therefore unnecessary, but in this type of instrument the

stranded steel wire was attached to the centre of a diaphragm made of pine fixed in a suitable case. The opening in the front was for speaking into, the one underneath communicating with the ear, by means of a tube, for receiving purposes.

Calling was effected usually by tapping the diaphragm with a pencil. Speaking was fairly good, but owing to the efficiency of the device being considerably reduced when the wire was attached to intermediate supports, the use of this means of communication was limited to a distance of from two to three hundred yards. One of the principal objections to the use of the taut wire was the nuisance caused, within the premises where the instruments were fixed, by the loud humming noise experienced when there was a breeze, the annoyance increasing in intensity when the wind was high.

Mr. Thornton expressed the belief that mechanical telephones were in use between two signal boxes not very far removed from one another at Tottenham, but that when the telephone patents expired electric telephones of various makes being placed on the market at cheap rates, the use of mechanical telephones was discontinued owing to the superiority of the former.

British Patent Specification No. 9962, in the name of A. M. Rosebrough, of August 22nd, 1885, relates to mechanical telephones and to arrangements for using combined electric and mechanical telephones. It made provision for a switchboard employing flexible conducting tubes for connecting one mechanical telephone line with another. Transmission between a mechanical and an electric telephone line was to be accomplished by means of a microphone arranged in proximity to the diaphragm of the mechanical receiving instrument. Signalling by electrical means was arranged for.

In spite of the several attractive features possessed by the mechanical telephone, its feeble transmission, with the other disabilities from which it suffered, definitely limited its field of use, and the undeniable superiority of the electric telephone, and the reduction in cost which followed competition in manufacture on the expiration of the patents, soon had the effect of ousting it from the market altogether. The mechanical telephone now has no practical value, but historically it possesses a certain interest and therefore finds a place in these chronicles.

CHAPTER VII

INTRODUCTION AND EARLY DEVELOPMENT OF THE MULTIPLE SWITCHBOARD, 1883–1890

SOME of the more important exchange switching devices used by the early telephone administrations in this country have already been briefly described and illustrated. With the fusion of the Bell and Edison interests, and the introduction of the Blake transmitter, the telephone may be said to have been fairly launched as a commercial concern. The business began to thrive in spite of the difficulties the United Telephone Company and others experienced, and it was soon realised that for exchanges in the larger towns, where development was greatest, improvements in the switching arrangements must be forthcoming if the anticipated future demands for service were to be provided for satisfactorily.

In America somewhat similar conditions obtained and, as the telephone was established there at an earlier date than in this country, and development had proceeded at a more rapid rate, prior consideration was given to the evolution of switching devices. The result was the production of a number of switchboards of comparatively small capacity and of different designs, amongst which the following may be mentioned :—

(*a*) Williams Switchboard made by Charles Williams, jun., of Boston; a modification of the Umschalter switch.

(*b*) Gilliland Switchboard. Of somewhat similar arrangement and design to the Williams board, but following more closely the design of the original Umschalter. While the Williams board was substantially made, the Gilliland was of much lighter and cheaper construction, the connecting strips being composed of metal stampings.

(*c*) Post Switchboard, also of the Umschalter type. A foot treadle was provided for working the ringing generator.

(*d*) Universal Switch manufactured by the Western Electric

Manufacturing Company, and designed and patented by Mr. C. E. Scribner. British Patent Specification No. 4903 of November 29th, 1879, describes this switchboard and gives a diagram of its connections. Mr. J. E. Kingsbury's book, " The Telephone and Telephone Exchanges," includes an illustration of it.

(*e*) Standard Switchboard manufactured by the Western Electric Manufacturing Company, a development of the Universal Switch, described and illustrated in Mr. Kingsbury's work.

(*f*) Williams Sliding Spring-peg Switchboard, briefly described n Chapter IV.

(*g*) Jones Switchboard manufactured by Jones Bros., of Cincinnati, also of the Umschalter type.

Some of these switchboards were available in 1883, and they were utilised eventually in various provincial towns in the United Kingdom, but none of them would accommodate more than 50 lines. For exchanges with a greater number of subscribers the method adopted in America, as in this country, was to fit a number of independent units, facilities for intercommunication being afforded by groups of transfer circuits provided between them.

Allusion has been made in Chapter III to the method adopted of building up 25 line sections of the switching bars of the Edison peg board, to form one large self-contained switchboard, and Fig. 17 is an illustration of a large Edison switchboard in use at one time at the Hop Exchange, London, and built up in this way. In this case the transfer lines were formed by coupling together certain of the horizontal bars in such a manner that they extended over several sections; they were thus available to more than one operator and afforded facilities for establishing connections between one operator's position and another.

The original switchboards employed by the Bell and Edison companies described were of distinct types and depended for their operation on entirely different principles. The Bell Company's switchboard was provided with slippers, jacks, and flexible cords for maintaining electrical connection between any two circuits; the Edison Company adopted a system of switching in which flexible connecting cords were unnecessary, utilising a switchboard of the Umschalter type. Thus at the inception of commercial telephony the relative merits of two different systems of affording facilities for telephonic intercommunication

came up for consideration and the vexed question of the cord board *versus* the cordless board originated. Each system had its adherents and those who viewed it with disfavour, and discussion transpired as to the advantages and disadvantages of the two. As related elsewhere in these records, numerous switching devices of the Umschalter type were devised and brought into practical operation for service at small exchanges and enjoyed great popularity; so long as the number of subscribers to be served remained comparatively small, reliable service was rendered by switchboards of this type, but the operating procedure was somewhat clumsy, as indeed it also was with the first Bell switchboard, when compared with present day methods. As, however, the number of subscribers steadily increased the cordless type of board, being less flexible than the switchboard provided with cords for connecting purposes, did not lend itself so readily to extension and, becoming unwieldy in the course of a comparatively short time was entirely discarded.

The conductors of the cords used on the switchboards employed by the Bell Company were composed of fine stranded wire and gave a good deal of trouble, but improved results were secured with the introduction at a later date of cords with conductors of tinsel.

The limitations of the switchboards of the Bell and Edison type, both of which continued for some time to be used by the United Telephone Company, were soon felt. The constant interchange of information between the connecting and answering operators of the Bell system and between operators in charge of the separate units comprising an Edison exchange was highly objectionable; the verbally expressed or otherwise intimated instructions were very disconcerting to the operators, and a certain amount of confusion and disorder was inevitable with this system of working. Furthermore, as already implied, no satisfactory means existed whereby an operator might ascertain readily whether or not the circuit of a subscriber terminating at some other position of the board with whom communication was desired was already engaged.

In London, the necessity for an improvement in switching methods had become apparent to Mr. F. B. O. Hawes, of the United Telephone Company, and led him to give thoughtful consideration to the question. He eventually conceived the idea

of the multiple switchboard, and two such boards, designed by him, were constructed in the United Telephone Company's own workshops; one was fitted in the Central Trunk Exchange in Oxford Court, Cannon Street, and brought into use on November 20th, 1883, and the other commenced to give service in the early part of the following year at the Chancery Lane Exchange.

In each case the multiple was horizontal or "flat," the idea being to permit of operators working on both sides. It was constructed somewhat in the form of a channel or trough and therefore earned the title of the "Hawes Trough" (horse trough). Further particulars of the Hawes multiple switchboard are given in Chapter III.

In America, the problems associated with the provision of facilities for telephonic communication in rapidly growing exchanges were precisely similar to those encountered in London and, to a less extent, elsewhere in this country. The idea of the multiple switchboard was originated in the United States, quite independently of Mr. Hawes, and, by virtue of the usual American enterprise and organising ability practised in telephone matters, was rapidly carried through to a successful issue. Thus the multiple switchboard was invented and developed by Americans in America, and although it has since been greatly improved upon, it first came to this country as a finished product and was accepted and utilised as such.

It is not proposed to attempt to trace in detail the various stages of its development in America. Such a record has already been compiled by Mr. J. E. Kingsbury, and a very full and interesting account of the evolution of the multiple switchboard up to the time of its introduction into this country is given in Chapter XIX of his book, "The Telephone and Telephone Exchanges."

According to Mr Kingsbury, Mr. L. B. Firman, general manager of the American District Telegraph Company, at Chicago, fitted multiple switchboards in that city as early as 1879, and a patent application was filed in the United States in respect of the invention on January 7th, 1881; therefore the credit for the conception of the multiple in America belongs to Firman and, in England, to Hawes, whom Firman forestalled.

The invention of the multiple has by some been ascribed to Mr. C. E. Scribner, but initially Scribner's part in this connection

appears more particularly to have been to devise a test system. It seems probable that the idea of the multiple may have been derived from the early practice of wiring together certain of the horizontal strips of two or more sections of the Edison or other switchboards of similar type, such as have already been described as akin to the Umschalter switch, situated in the same room, for the purpose of providing facilities for intercommunication.

To devise a means whereby an operator might quickly ascertain whether or not a line terminating at another position was engaged, appears, however, to have been a matter much more involved, and presenting greater difficulties, than the conception and design of the multiple system only.

In addition to describing the Universal Switch devised by Mr. C. E. Scribner, British Patent Specification No. 4903, dated November 29th, 1879, describes a multiple test system also invented by him and a later patent by Mr. Scribner, recorded in British Patent Specification No. 3116, of June 22nd, 1883, in the name of S. Pitt, gives particulars of a test system forming the basis of the system ultimately adopted generally and which is now in universal use throughout the world.

Firman and Scribner, with several other Americans, developed the ideas they had evolved, and the result was the production by the Western Electric Manufacturing Company of Chicago of a multiple switchboard of comprehensive arrangement and design.

The multiple switchboard designed by Mr. Hawes in this country had a multiple arranged flatwise or horizontal, whereas in the American board, which was placed on the market in 1883, the multiple was upright or vertical. The indicators or annunciators, as they were usually termed in America, were arranged immediately above the key shelf; above the indicators were the multiple jacks and above these again was the plug shelf accommodating the plugs and cords, together with the clearing indicators associated therewith. The plugs and cords were thus overhead, being the inverse of the modern arrangement and in removing a plug from its socket the operator had to reach upwards and draw it downwards, instead of lifting it upwards as is the present day practice. The cord pulleys were supported on overhead racks situated above the switchboard proper.

This overhead arrangement of plugs and cords appears strange

when contrasted with the present day system : it was, however, quickly abandoned by the Western Electric Company in favour of an arrangement similar to the one now in general use. Liverpool was the first city in this country to be equipped with a Western Electric switchboard of the type referred to.

Early telephone development in Liverpool was markedly brisk, difficulty being experienced in complying with demands received for telephone service and in disposing of the complexities of switching brought about by connecting up the numerous applicants for telephone service. The switching equipment originally provided at Liverpool was almost identical with that at the first London Exchange, viz., 36 Coleman Street. The author is

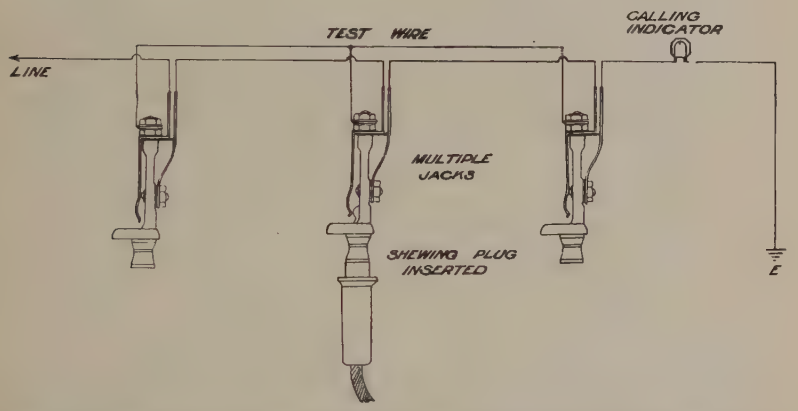

FIG. 65.—Multiple Line Connections, Liverpool earth circuit switchboard, 1884.

indebted to Mr. T. Cornfoot, of Liverpool, for the photograph reproduced in Fig. 42. This illustration will give some indication of the extent to which the Liverpool Exchange had grown by 1884, when the photograph was taken. It will, no doubt, be difficult for modern telephone engineers to associate the apparent disorderly medley of apparatus depicted with a telephone exchange.

The Lancashire and Cheshire Telephonic Exchange Co., Ltd., arranged for the most up-to-date equipment available to be provided, the last word in American telephone switching mechanism was requisitioned, and subsequently installed by the contractors, the Western Electric Company. Fig. 64, reproduced from a photograph originally published in the *Electrical*

Review (London) for October 18th, 1884, gives a general view of the completed exchange. The switchboard was brought into service in 1884 and was housed in the dome of the Liverpool

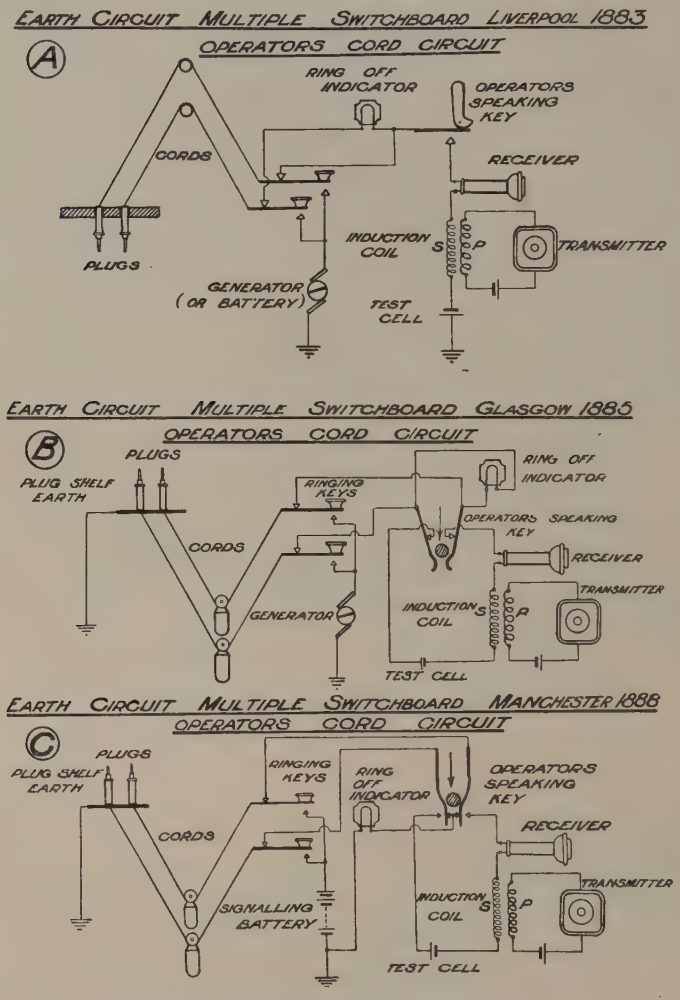

FIG. 66.—Operators' Cord Circuits.

(*A*) Earth Circuit Multiple Switchboard, Liverpool, 1883.
(*B*) Earth Circuit Multiple Switchboard, Glasgow, 1885.
(*C*) Earth Circuit Multiple Switchboard, Manchester, 1888.

Cotton Exchange. The wiring of the multiple and the connections of the operator's cord circuit are diagrammatically shown in Figs. 65 and 66 (*A*) respectively.

FIG. 64.—First Western Electric Upright Multiple Switchboard in the United Kingdom, Liverpool, 1884.

(From a photograph loaned by Mr. Archer Smith.)

[*To face page* 164.

FIG. 67.—Liverpool Exchange, showing extension to switchboard illustrated in Fig. 64, 1889.

(From a photograph loaned by Mr. T. Cornfoot.)

[*To face page* 165.

It will be observed that the board was an earth circuit board and was unsuited for the accommodation of metallic circuits, in those days of comparatively rare occurrence. The original battery ringing subscribers' telephones were at first retained in service, and were worked for a short time in conjunction with the new multiple switchboard; they were, however, eventually replaced by instruments provided with magnetos for signalling purposes.

From Fig. 64 it may be seen that the transmitters were of the Blake type, and were contained in somewhat bulky wooden cases suspended as a fixture from the overhead plug shelf; also that the receivers, of the Bell single pole type, were held in the hand. It was found that the transmitter cases obstructed the operator's view of the multiple jacks, and impeded her movements in plugging into the multiple; accordingly they were removed to the top of the switchboard. To convey the sound of the operator's voice to the transmitter a long curved tube with a mouthpiece attached, was fitted to it in such a manner that the mouthpiece was situated at a convenient height for speaking. These tubes were commonly and not inaptly termed " elephant trunks." Some of them may perhaps be discerned on the extreme right of Fig. 67, from a photograph secured after an additional switchboard, to be referred to immediately, had been fitted in the same room. It seems doubtful whether any real advantage was derived from the use of these tubes, and certainly, as later experience has shown, the quality of transmission would not be improved.

Telephone development in Liverpool was such that the provision of additional switching facilities soon became necessary, and Fig. 67 is a view of an additional switchboard of a later type, provided as an extension to, and alongside of, the original multiple equipment fitted in 1884. The extension was fitted as an independent switchboard, and was provided with transfer junctions to the existing equipment for purposes of intercommunication between subscribers whose lines were not answered at the same board. The small switchboards seen in the centre of the room were utilised for trunk working. The first trunk lines connecting Liverpool with London were terminated on these sections, and were provided with special three minute timing facilities.

From 1883 onwards the development of the multiple switchboard progressed rapidly and the Western Electric Manufacturing

Company, who owned the patent rights, quickly introduced important improvements in both design and construction.

In the board fitted at Liverpool there were no answering or home jacks and, in order to avoid the confusion which otherwise might have occurred amongst the operators in answering, arrangements were made whereby the jacks of the subscribers allotted to each operator for answering purposes were brought as nearly as was practicable directly in front of her.

One of the first improvements to be made was the provision of answering jacks, in addition to the multiple jacks, in order that the answering positions for each operator might be concentrated immediately before her. The operating efficiency was thereby increased.

Improvements in the design, method of insulation, and assemblage of the jacks were also made. The jacks fitted in the first multiple switchboard at Liverpool were mounted singly on wood in blocks of 100, consisting of five horizontal rows each of twenty jacks and measuring 15 inches by 5 inches. They were fitted with springs of phosphor-bronze. In the improved jacks the springs were formed of German silver, and were supplied in strips of twenty, with hard rubber insulation measuring $11\frac{1}{2}$ inches by $\frac{5}{8}$ inch. A later improvement was in a further reduction in the width of the jack strip to $\frac{1}{2}$ inch which remained standard for magneto boards in this country.

The construction, arrangement and mounting of the indicators were also improved in that they were supplied in strips of ten indicators each, fifteen inches long.

In a paper by Mr. J. E. Kingsbury, entitled, "The Origin and Development of the Telephone Switchboard," read before the Institution of Electrical Engineers on January 24th, 1895, occurs the following interesting paragraph relative to the invention of the spring jack, plug and indicator used in the early switchboards manufactured by the Western Electric Company.

"It may be of interest to state that the inventor of the spring jack and plug is Mr. C. J. Warner, one of the oldest of the expert staff of the Western Electric Company. Mr. Warner designed, not only the jack, but also the indicator used on these switchboards. He brought to the design of telephone apparatus a wide experience, and you will probably agree with me that he graduated in a good school. Born in London in 1822, Mr. Warner became engaged

in the manufacture of electrical apparatus in the workshop in which instruments were made for Cooke and Wheatstone. Subsequently he made some apparatus for experimental use by Morse on the line between Baltimore and Washington."

A further improvement was the adoption generally of dummy end half-sections, in order that the operator at the end of the board might be within range of a complete multiple.

The Liverpool switchboard appears to have been the first large board in this country in which the plugs and cords were an attached part of the switchboard equipment and where pulleys and weights were used to maintain the cords at suitable tension.

All these improvements were brought into being in or before the year 1884, and were quickly taken advantage of by telephone companies operating in this country. The first board to be fitted here embodying the improvements alluded to was brought into service at Glasgow in 1885 to be quickly followed by a similar board at Sunderland. The Glasgow board was made up of five-panel four-position sections. The transmitters were originally of the Blake type, contained in wooden cases, and mounted on pillars of convenient height affixed along the centre of the keyboard. Single pole bell receivers were provided; when not in use each receiver rested in a cradle switch, mounted on the keyshelf, which disconnected the primary circuit.

The Western Electric Manufacturing Company were the sole patentees and producers of the multiple switchboard at this date, and telephone administrations in all parts of the world had at this time therefore no experience whatever to qualify them for the work of installation; the Western Electric Company were consequently in a unique position, and not only did they supply the switchboards they produced, but they were also called upon to undertake their erection. Experts of the firm were sent over from America to superintend the installation of the switchboards already mentioned at Liverpool and Glasgow. The case of Sunderland, referred to as the third multiple board fitted in this country, is interesting as being the first case when the erection of a Western Electric Multiple Switchboard was undertaken in this country without the aid of experts from America. Mr. C. B. Clay, the general manager of the Northern District Company, visited Glasgow, and in company with his electrician studied the board there for a day or two. He was satisfied that the board

for Sunderland could be installed by his own staff without outside assistance, and by his insistence and under his own direction the work was satisfactorily accomplished, the board working efficiently from the outset.

While the new board was being fitted the subscribers in Sunderland were temporarily served by the improvised exchange illustrated in Fig. 48.

Other multiple switchboards of the Western Electric type quickly followed, in London first at Queen Victoria Street, later known as "Bank," and afterwards at Cornhill, Chancery Lane, Smithfield, and Westminster, and in the Provinces the principal towns were very soon provided with the latest multiple switching equipment according to urgency.

In 1888, a Western Electric earth circuit multiple switchboard was installed at the Royal Exchange, Manchester. It embodied some special features and at the time was generally considered to be the finest and best equipped exchange in the United Kingdom.

The calling and clearing signals were operated by battery current, and battery operated bells were employed on subscribers' instruments. The circuits were arranged so as to permit of one subscriber ringing through to another without actuating the ring-off signals.

Each section comprised six panels and accommodated three operators. There were four groups of fifty subscribers' indicators, making in all 200 per section. Each operator's position was equipped with fifteen pairs of plugs and cords with the associated ring-off indicators and speaking and ringing keys. Bell receivers, held in the hand, and Blake transmitters, suspended from above, were used by the operators.

Instead of the local, or home jack, being the last jack to be connected on the switchboard, it was included in circuit with the multiple wiring at the home position, with the object of reducing, as far as possible, the length of switchboard cable in circuit during the time a connection between two subscribers was established; otherwise the multiple connections were similar to those illustrated in Fig. 65.

The switchboard was designed for an ultimate capacity of 4200 but was initially fitted for 1600 subscribers.

In Fig. 66 at (*C*), the connections of the operator's cord circuit

are shown and it will be observed that the ring-off indicator was connected in shunt with the line, instead of in series, as was the case in the switchboards at Liverpool and Glasgow previously referred to.

Thus within the period to which this chapter has reference the multiple switchboard became recognised in this country as the only practicable method of dealing satisfactorily with the traffic to be handled in telephone exchanges of appreciable size.

The principle of the multiple being thus established, great developments took place in the course of the next few years; the chief of these are recounted in Chapter XI.

CHAPTER VIII

EARLY UNDERGROUND CABLE SYSTEMS FOR TELEGRAPH AND TELEPHONE CIRCUITS, 1823–1890

For more than thirty years prior to the advent of the telephone, consideration had been given to the provision of underground telegraph lines; numerous practical trials had been made, and although first efforts were not attended with permanent success, due, no doubt, mostly to lack of experience, a certain amount of progress had been made.

In order that the sequence of events relating to the provision of underground telephone lines may be followed readily, it is therefore necessary to trace the connecting link bridging the use of underground circuits for telegraph and telephone purposes, and to hark back to the time when underground work was first provided for telegraph lines.

It is not intended to enter into contemplation of all the various investigations and experiments conducted preparatory to the introduction of underground electrical circuits as a practical proposition, but merely to give a brief review of the chief events which transpired prior to the establishment of underground circuits on a more or less permanent basis.

In the light of present day knowledge and experience it is, perhaps, not easy to appreciate the difficulties and problems which confronted the early telegraph and telephone engineers in the design and provision of underground circuits.

During the ten years succeeding the introduction of the telegraph in 1837, various expedients were tried with the intention of producing satisfactory means for the insulation of underground wires; shellac, resin, gas-tar, asphalt, bitumen, and bituminous compounds, pitch, sulphur, beads of glass, spun glass, and other materials were suggested and tried, some of them in conjunction with cotton-covered wires enveloped in a lead sheath, but it was not until the introduction of gutta percha as an insulating material in 1847 that any real success was achieved.

The origin of all our present day systems of underground conductors for electrical purposes generally was an experimental underground line laid by Mr. (later Sir Francis) Ronalds in his private garden at Hammersmith in the year 1816.

A full account of the experiments then carried out appears in a small book published by Mr. Ronalds in 1823, entitled, "Description of an Electric Telegraph and of some other Electrical Apparatus." A wooden trough, about two inches in cross section, treated with pitch, was sunk in a trench about 4 feet deep for a distance of 525 feet. Lengths of stout glass tube were joined together by shorter lengths of similar tube of slightly larger diameter, by means of wax, wax being used in order to permit of expansion and contraction caused by variations in temperature. A copper wire was drawn through the conduit thus formed by the sections of glass tube, the whole embedded in pitch in the wooden trough, and a cover to the latter was fixed in position before the pitch cooled. Several suggestions were made by Sir Francis Ronalds for underground telegraph lines.

Mr. W. H. (afterwards Sir William) Preece, in contributing to a discussion after the reading of a paper, entitled, "Underground Telegraphs," by Mr. C. T. Fleetwood before the Society of Telegraph Engineers and Electricians on May 26th, 1887, thus commented upon the work of Sir Francis Ronalds—

"There are two great historical points of interest that have been brought before us by Mr. Fleetwood. First that in the year 1823 Mr. Ronalds wrote a paper on Underground Telegraphs that would do credit to any member of this Society if written in the year 1887. It is perfectly astonishing how that man's instinct saw the various troubles that were likely to be met with in the construction of long underground lines. The paper is to be found in the Ronalds library; it is a pamphlet that is well worth studying by everybody here."

In 1837, Messrs. Cooke and Wheatstone, of early telegraph fame, took out a patent which included an idea for laying underground conductors and in the same year the system was employed to establish telegraphic communication between Euston Station and Camden Town. It consisted of five copper wires covered with cotton treated with a preparation of resin, laid in grooves cut longitudinally in a piece of timber of trapezoidal section. The grooves were afterwards covered with strips of wood, and

the whole was enveloped in pitch and buried in the ground. Samples of this line, recovered after about thirty years, are now in the Science Museum at South Kensington.

In 1838 a patent was entered by the same two gentlemen for laying wires formed into a cable in iron piping, and the method was applied in practice on the Great Western Railway in 1839.

In 1846, a 3 inch cast iron spigot and socket pipe was employed to accommodate two cables between the offices of the Electric Telegraph Company, at 345 Strand, and Nine Elms Station. Each of the cables consisted of four copper wires covered with two layers of cotton, impregnated with a mixture of tar, resin and grease contained within a lead tube about $\frac{1}{2}$ an inch in diameter, covered with tarred yarn. The cable was laid in lengths of about 50 yards, and each of the intervening joints was made secure by means of a lead sleeve soldered to the lead tube at either end.

Mr. Cooke undertook practically all the construction work associated with the names of Cooke and Wheatstone, and in attempts to discover the most suitable material for dielectric he experimented, and made practical trials, with such materials as cotton, hemp, silk, glass, resin, shellac, pitch, bitumen, Stockholm tar and grease. As a protection, wood troughing, lead tubing, iron pipe and troughing, and earthenware pipes were tried.

A most interesting cable system was introduced on certain British railways, viz., the Blackwall, London, the Leeds and Manchester, the Edinburgh and Glasgow, and the Great Western railways prior to the year 1843. The system was referred to in a paper read by Mr. A. Watts before the Manchester Telephone Society on January 15th, 1904, on "The Evolution of Underground Work," and is also mentioned on page 16 of Volume IV of the *National Telephone Journal*. It was described in articles in the *Engineering Magazine*, and also in the *Practical Mechanic* of July 1843. The system was devised for telegraph purposes by Mr. William Fothergill Cooke, and was to all intents and purposes a dry core cable system. The wires were of copper, covered with cotton, and afterwards treated with varnish, and were contained in air-tight iron tubing, laid either in the ground or supported on short posts and protected by a wooden rail. At terminations of the pipe the wires were sealed with composition, in order to render the system of piping air-tight, insulation being dependent upon the exclusion of moisture. Loss of insulation

was denoted by a device invented by Mr. Cooke, which he termed a "detector," probably the forerunner of the present day lineman's detector now so generally used; if due to penetration of moisture, the loss could be corrected by blowing through the pipe a draught of dry air from a reservoir. The pipe containing the cotton-covered wires was, in fact, kept charged with air, supplied by the reservoir mentioned, at the low pressure of 3 lb. per square inch above atmospheric pressure, this being considered sufficient to exclude the greatest pressure of water to which the pipes were likely to be subjected. The apparatus by which this

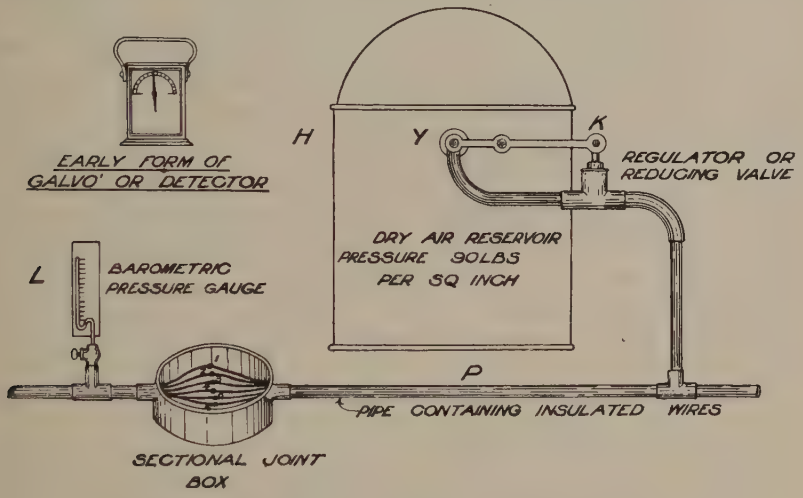

Fig. 68.—Cooke's Dry Air System of Telegraph Cable, 1843.

was accomplished is illustrated in Fig. 68, drafted from information given by Mr. Watts in the paper above referred to.

The system of pipe was connected through a reducing valve, or regulating device, to the dry air reservoir and by its means the required pressure of 3 lb. per square inch was maintained; any loss of air occurring in the pipe system was immediately replenished from the compressed air within the reservoir.

Although, in this interesting system, insulation depended upon the material used to cover the wires, it also depended upon the covering being maintained in a perfectly dry condition. It appears to be the first instance of the utilisation of dry air in a cable system to sustain a satisfactory state of insulation, and therefore

Mr. Cooke's system may not unreasonably be regarded as the forerunner of the present day dry core cable.

The system was ultimately abandoned owing to its high initial cost, and to the difficulty of localising defects and of remedying them when found; the circuits were displaced by overhead conductors. The idea apparently lay dormant until the invention of dry core cable in America in 1891.

A few words relative to the genesis of gutta percha, a substance which has played such an important part in the insulation of underground and sub-aqueous conductors for both telegraph and telephone purposes, may not be out of place. The gutta percha of commerce is the treated juice of the *Isonandra gutta*, or *Isonandra percha* tree, a large tree of the *Sapodilla* order called also the Taban tree, indigenous to all the islands of the Malayan Archipelago, Southern Asia and Dutch Guinea. Dr. W. Montgomerie, an assistant surgeon in the service of the East India Company, first observed the methods of extraction adopted by natives, and the various uses they made of the product; he was instrumental in introducing it to this country in 1842. The chief supply was from Singapore. The term gutta percha is of Malayan origin, gutta meaning gum or juice of a plant, and percha having reference to the tree. Gutta percha is of similar composition and derivation to india rubber, but the two substances are quite distinct and possess entirely dissimilar properties. Gutta percha readily oxidises when exposed to the air, particularly at temperatures over 75° F., losing those properties which make it specially suitable as an electrical insulator. Exposure to the light and heat of the sun's rays facilitates oxidation. If preserved from light, and kept at a moderately cool and even temperature, its state of preservation is extended very considerably. Under water, oxidation is prevented, deterioration is arrested, and its life consequently extended.

It is believed that it was Faraday who first called attention to the excellent insulating properties of gutta percha, and to its suitability for use as a dielectric. In 1848, considerable attention was given to the invention of methods for applying gutta percha to wires for electrical purposes. Patents were taken out in the same year, and gutta percha insulated wires were first employed in 1849.

Although gutta percha was known to be a material possessing

high insulating qualities, its initial use as an insulating covering for underground wires was not attended with success, largely because of lack of experience in applying the gutta percha to the conductor.

One of the first practical trials made in 1849 was beneath the streets of London, where it proved an utter failure. It was not until some experience had been gained, and improvements in manufacture introduced, chiefly in the direction of increasing the number of coatings, that the efforts made were attended with a modicum of success. As many as twenty layers were at one time applied to one wire, in order that an imperfection in one layer, which might readily occur, should be covered by the next. Ordinarily five layers were considered sufficient. The wire was usually coated with an adhesive mixture consisting of one part Stockholm tar, one part resin and three parts gutta percha (Chatterton's Compound) and the same mixture was also applied between coatings. The chief consideration in dealing with gutta percha was cleanliness, usually secured by washing with naphtha. Gutta percha was found to deteriorate rapidly in ground impregnated with coal gas.

Gutta percha-insulated wires enclosed in a lead sheath were laid extensively in Prussia, but after a few years, owing to difficulties experienced in working them through failure of the lead sheath and the gutta percha, they were abandoned and replaced by overhead wires.

After somewhat similar experience, gutta percha-insulated wires were abandoned in France.

The telegraph companies in this country were, however, a little more successful.

In Fig. 69 (*A*) is given a section of a wooden troughing, containing copper wires of No. 18 gauge, insulated with gutta percha, an arrangement extensively used in this country by the Magnetic Telegraph Company shortly after the introduction of gutta percha-insulated conductors for telegraph purposes.

Another form of troughing was used in 1853 for the Manchester–London subterranean line, one of the first to be laid in this country; it is illustrated in Fig. 69 (*B*). In this case, a wooden cover was used and the ten gutta percha-insulated copper wires of No. 18 gauge were enveloped in a serving of tarred jute as additional protection; incidentally, as the whole could be laid at one operation, a saving in labour was secured. The idea of the

multiple cable was probably evolved from the bunching together of individual wires in this manner.

In places where an underground system was likely to be subjected to disturbance by subsequent excavations for the laying of gas, water, drain pipes, etc., for example, where it passed through the paved streets of towns, cast iron pipes were used.

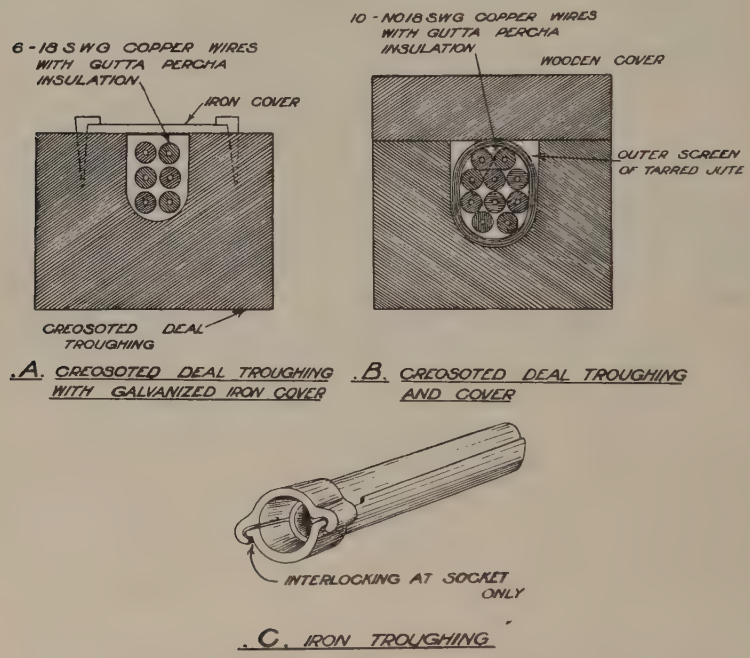
6-18 S.W.G. COPPER WIRES WITH GUTTA PERCHA INSULATION
IRON COVER
CREOSOTED DEAL TROUGHING
10-NO 18 S.W.G. COPPER WIRES WITH GUTTA PERCHA INSULATION
WOODEN COVER
OUTER SCREEN OF TARRED JUTE
A. CREOSOTED DEAL TROUGHING WITH GALVANIZED IRON COVER
B. CREOSOTED DEAL TROUGHING AND COVER
INTERLOCKING AT SOCKET ONLY
C. IRON TROUGHING

FIG. 69.—Early Underground Cable Systems for telegraph purposes.

(*A*) Wooden Troughing with gutta percha-covered wires used by the Magnetic Telegraph Company.

(*B*) Wooden Troughing with gutta percha-covered wires used by early telegraph companies.

(*C*) Channel Iron Conduit of cast iron used by early telegraph companies for protection of gutta percha-insulated wires.

Between London and Manchester lengths amounting to 21½ miles out of a total of 200 miles were composed of cast iron pipes. It was found, however, that the operation of drawing the gutta percha-covered wires into the cast iron pipes was frequently attended with injury to the insulated conductors. Abrasion, or breakage of the insulation, and parting of the conductor within, was experienced and although the injury was not always observed at the time, it became apparent subsequently as a fault.

In order to avoid such abrasion and mechanical injury, conduits of cast iron, formed of two channels, of half-circular section, were introduced in 1852 by Sir Charles Bright, engineer to the Magnetic Telegraph Company. The cables were placed in position after the lower half of the conduit was laid and the upper or inverted half was finally placed over them. The two halves were secured by bolts and nuts passing through holes in semi-circular lugs, cast in coincidence, on each half.

Other types of channel conduit, both of rectangular and semi-circular form, were devised and used. One form, designed, it is believed, by Mr. Thomas Reid, of the firm of Reid Bros. of London, is illustrated in Fig. 69 (*C*). In this type, apparently no steps were taken to unite mechanically the upper and lower halves of the conduit, which were held in position by the formation of the flanges or webs. The cast iron channels were 6 feet long, approximately 2 inches in internal diameter and the thickness of the material was $\frac{3}{8}$ inch. Quantities of cast iron channel pipe were laid in London, Manchester, Liverpool, Newcastle-on-Tyne, Carlisle, Glasgow and other towns.

The name of Thomas Reid is intimately associated with early telegraph history. The firm of Reid Bros., one of the oldest firms of telegraph engineers and contractors in the world, dates back as far as 1813; they commenced the manufacture of telegraphic apparatus in 1859, and devised a multiple core lead-covered cable for telegraph purposes.

In 1853 an underground telegraph line was laid by Messrs. Reid Bros. for the Magnetic Telegraph Company between Glasgow and Carlisle. The conduit was of cast iron, in the form of two channels of half-circular section, one being fitted over the other. The wires were insulated with gutta percha.

Sections of discarded underground work, composed of conductors insulated with gutta percha, have been unearthed, from time to time, in numerous parts of the country, during the course of excavations made for various purposes; the remarkably good state of preservation of the gutta percha was a feature commented upon on certain occasions. These were all laid by or for the old telegraph companies.

The various underground systems utilising gutta percha for insulation and installed by the early telegraph companies had not, however, a very long life. Installed in the period 1848–1854,

they were practically all abandoned and replaced by open wire lines within a period of 10 years. Present day engineers who have had experience in the installation and upkeep of gutta percha-insulated wires, now practically extinct, will appreciate the difficulties in maintenance of such long lengths as were represented by London to Manchester and Liverpool, London to Dover, Glasgow to Carlisle, and especially when a draw-in system was not adopted. Methods of manufacture, particularly the application of the gutta percha to the conductor, were not perfected, and the insulation was, therefore, unreliable. Moreover, the work of installation was very rapidly carried out and probably the requisite care and cleanliness were not observed in either laying or jointing, a feature fatal to the satisfactory performance of gutta percha-covered wires, as has since been learnt by experience.

By the year 1870, when the British Post Office acquired the telegraphs of this country, considerable improvements in the manufacture of gutta percha-covered wire had been made; from this time, until after the introduction of the dry core paper cable in 1891, a period of 20 years, gutta percha was recognised by the Post Office as standard insulation for subterranean telegraphs, and quantities were laid in London and the important towns in the Provinces. Overhead telegraph lines erected along main roads, and carried underground through towns where difficulty was experienced in carrying them overhead, was the recognised practice. Single gutta percha-covered wires, of excellent quality and manufacture, were drawn into cast iron pipes, ranging from 2 to 6 inches in diameter, previously laid for their reception, and inspection boxes were arranged at suitable intervals, to permit of drawing-in and jointing operations, and subsequent inspection and testing.

Interesting information relating to the early use of underground conductors for telegraph purposes is contained in Mr. John Christie's "Manual of Telegraph Construction."

Some further information of much interest relative to the employment of various types of underground conductor in the early days of the telegraph is also given in the paper previously referred to, entitled "Underground Telegraphs," read by Mr. C. T. Fleetwood before the Society of Telegraph Engineers and Electricians on May 26th, 1887.

Gutta percha, therefore, was commonly accepted as the uni-

versal insulating material for telegraph purposes at the time telephony was introduced, and its adoption for telephone purposes, where underground conductors were required, followed as a natural consequence. Single gutta percha-insulated wires, taped and braided for protection, were used for some time, but were replaced by a 4 wire or "quad" cable in about 1882. These cables were extensively and successfully used in towns and places where it was necessary to instal underground circuits. In Newcastle-on-Tyne, for example, both the Post Office and Northern District Telephone Company's telephone line systems, were comprised of gutta percha-insulated wires drawn into cast iron pipes of 2 inches and 3 inches internal diameter, accommodating respectively 18 and 36 pairs of wires as a maximum.

In certain other places, similar methods were adopted, earthenware drain pipes of 2 inches or 3 inches internal diameter and other convenient ducts of various types being utilised. For the most part, however, early telephone systems were entirely overhead, the case of Newcastle-on-Tyne being exceptional.

During the few years immediately preceding and following the introduction of telephony, numerous expedients were tried with a view to the production of an insulating material to take the place of gutta percha, then the only suitable substance known, possessing the requisite permanent insulating properties, for underground cable circuits.

Gutta percha possessed several disadvantages. It was expensive, and supplies of the raw material were not plentiful, its inductive capacity was high, and the utmost care and cleanliness in jointing were essential to success in the completed circuit. It was susceptible to heat and could not with safety be exposed, even to the direct rays of the sun, for long periods. Incidentally, it may be mentioned that the heat from bakers' ovens in London and elsewhere has been known to melt the gutta percha from the conductors enclosed in pipes passing over them. The space per circuit occupied was considerable, one 3 inch pipe affording accommodation for no more than about 36 circuits. For underground work, the last-mentioned consideration was an important one, particularly when considered in the light of the rapid increase in the number of telephone circuits experienced and the capital cost of duct accommodation.

Since its introduction into Europe, in the early part of the 18th

century, india rubber has played a most important part in electrical engineering, not excluding telephony, and therefore some information respecting its derivation and early treatment forms a part of telephone history which may, not irrelevantly, be dealt with here.

India rubber, caoutchouc or gum elastic occurs in suspension in the milky juice of several tropical and some few European plants. The *Siphonia cahuchu* or caoutchouc, a tree flourishing in South and Central America and Java, formerly yielded the greater part of the best rubber used in commerce. It was chiefly obtained *via* Para, hence the term Para rubber. Several other trees of similar order abound in the islands of the Indian Archipelago and the East Indies. Like gutta percha, it is a hydrocarbon, and its composition has been variously determined by different authorities. Exposure to air and light induces gradual oxidation and consequent deterioration. It yields water by distillation. It is a bad conductor of heat. Its combination or treatment with sulphur, a process termed vulcanisation, invented by Goodyear in 1844, renders it suitable for commercial use. Ebonite and vulcanite merely consist of vulcanised rubber prepared in a particular manner.

The following extract from Mr. John Christie Douglas' " Manual of Telegraph Construction," published in 1877, gives interesting information concerning the use and relative merits of india rubber and gutta percha as they were regarded at that date.

" As compared with gutta percha, India rubber has the following advantages: It is not affected by elevation of temperature below 212° F., whereas gutta percha core is softened at 120° to 130° F., it is a better insulator, and has a lower inductive capacity than gutta percha. It is more resilient and therefore far less liable to mechanical injury. A vehicle may be driven over rubber core without sensibly flattening it permanently. Hooper's core is much more durable than gutta percha when exposed in the tropics. India rubber core is more flexible than gutta percha core, and is, therefore, better suited for movable connections. The disadvantages of india rubber are the following: It absorbs more water than gutta percha, both materials absorb much less in salt- than fresh-water; the absorption of gutta percha is very slight indeed in salt-water—this absorption is not found to reduce the insulating property to an extent of practical importance in thick masses, as ordinary covered wire, but in thin plates it seriously impairs this property. Hitherto india rubber could not

be safely joined, but this difficulty is got over in Hooper's core; the system of cooking under a jacket seems to effectually consolidate the whole without damaging the pure rubber by heat, and the joints made in the finished core appear perfect. India rubber becomes viscid in contact with copper, but this is got over by coating the copper with tin, and although the rubber has been found slightly sticky, this does not appear to occur to an injurious extent, and probably does not occur at all under water. The sulphur in the vulcanised rubber in some cases has been found to have slightly attacked the metal, but to an insignificant extent. India rubber is affected by greasy matters which preserve gutta percha, such as boiled and raw linseed oil. India rubber is not uniform in quality as gutta percha, and mixed qualities are inferior in durability, but this objection has no force if the rubber be vulcanised. Gutta percha core can be more readily joined than India rubber core, as the latter requires cooking; this is a great objection to the use of this material for underground wires in towns and for some other purposes, but is of less moment in the case of a cable. The great objection to the use of india rubber was the fact that as gutta percha had been studied and was well understood, it was better to keep to the employment of the material than commence anew to risk capital on an untried material, gutta percha having been successfully applied only after many costly failures; but at present there are more data on which to base a judgment. From information furnished by the manufacturers, it appears upward of 9000 miles of Hooper's submarine cables have been laid or are to be laid, including 5000 miles for the Great Western Company, and a sample cable was laid as long ago as 1863. There is much difference of opinion on the subject. The engineer can, however, now examine for himself into the respective merits of cables actually in operation. Various compounds of india rubber with shellac, gutta percha and other matters have been proposed from time to time; one of the best is Wray's Compound. This is composed of shellac, india rubber and powdered silica or alumina, and about one-ninth gutta percha; it is put on with a die, but is obviously inferior to vulcanised india rubber."

Patent Specification No. 10799 of 1845 is not without its significance in connection with the evolution of the telegraph and telephone lead-covered cable. In this specification, William Young, of Paisley, manufacturer and dyer, and Archibald McNair, of the same town, merchant, describe their invention of "Certain Improvements in the construction and Means of Manufacturing Apparatus for Conducting Electricity." The specification disclaimed as part of the invention the adaptation of wires surrounded

with non-conducting substances enclosed in tubes, and had particular reference to an improved method of manufacture; nevertheless it provided that copper, iron or other metallic or mixed metallic wires might be covered with cotton, woollen or linen thread in a manner similar to those termed bobbin wires used in the manufacture of caps and bonnets; preferably the wires might be covered with threads in a plaited or braided form by means of a braiding machine, such description of covering being considered of material importance in the construction of electrical conductors. The wires so covered were to be enclosed in a pipe of lead or other similar soft metal, and impregnated with asphalt, pitch, wax, resin or other suitable non-conductor, capable of being liquefied by heat, by one series of operations, in one machine. The machine, the principal subject of the specification, received the braided wires, impregnated them with the filling material and enclosed them in a lead tube. The chief features of this machine were, perhaps, the provision of a vertical hollow mandrel communicating with a tank containing the impregnating material, through which was passed the assembled wires, and a hollow circular die, by means of which molten lead, under the influence of hydraulic pressure, was formed into a circular and continuous sheath surrounding the insulated wires. Two machines for accomplishing the same object were described in the specification, but they differed in immaterial detail only.

The specification also provided for the use of the improved system of conductors for telegraphs, either by land or water, also for firing mines or other purposes for which electric conductors have been or might thereafter be employed. By this provision its application to telephone requirements was therefore anticipated. It was provided that the lead sheath might be utilised as a means for completing single wire circuits. Provision was also made for the improved conductors or cable, as they would now be termed, to be manufactured in long lengths and rolled on reels. The reels or drums might be carried on a wheeled carriage; and in laying operations one end of the cable was held fast while the carriage was made to travel in the direction in which it was to be laid, the reel revolving on its centres and allowing the pipe containing the wires to be unwound and delivered on the ground with great facility. If the cable was to be laid in water, a floating vessel was to be used. At regular or convenient

distances, the ends of the pipes might be raised above the ground and placed in a cast iron or other suitable box. Circuits were electrically connected within the boxes by means of pinching screws or mercury cups, and by these means points of easy access to the conductors for testing and other purposes were provided.

The system thus devised by Messrs. Young and McNair as early as 1845 seems to have been the first serious attempt to transfer to the factory much of the work previously carried out on the site of installation, the work of assembling, forming, impregnating and furnishing mechanical protection in the form of the lead sheath all being carried out in the factory; the hollow mandrel in conjunction with the special circular die provided means for applying a continuous sheathing of lead to the cable core. Generally considered, Messrs. Young and McNair's invention was a very notable advance in the construction of underground electrical conductors, but it was not made full use of for many years.

Another British Patent Specification which, in spite of its relative antiquity, had an important bearing on the production of cable subsequently used for telephone purposes was No. 3587 dated December 11th, 1869. This specification was filed by William Alfred Marshall, of Canonbury, in the County of Middlesex, telegraphic engineer, and related to " Improvements in the Manufacture of Electric Telegraph Cables, and in Apparatus employed therein."

Cotton or other non-conducting fibrous material, previously dried and heated by boiling in paraffin wax, was applied spirally to the conducting wires in the form of cords or strands. A space was left between each strand, and alternate layers were to be applied in reverse directions. The requisite number of wires thus treated was formed into a cable, of length suited to the process, and the whole drawn through a straight length of lead or other soft metal tube. One mode mentioned in the specification of introducing the wires was to first draw a pith ball through the tube by means of an air pump; to the ball was attached a light line of increasing strength by which the wire or wires were finally drawn through. The tube, with the paraffined cotton-covered wires within it, was then wound upon a skeleton drum furnished with a spindle, one of the journals of which was made hollow. To this journal, the end of the tube containing the wires innermost upon the drum was connected. The drum was then

to be supported upon standards in a tank (or alternatively a hot air chamber) and the hollow journal connected by a pipe to a tank containing paraffin wax in a liquid state forming a source of supply. The tank containing the drum was then filled with paraffin wax, maintained at a suitable temperature together with the wax in the supply tank by an arrangement of gas jets or other convenient means. A vacuum pump was then applied to the free end of the cable on the drum, and, as soon as the requisite vacuum was obtained, wax was admitted by opening a stop-cock provided in the pipe between the hollow mandrel of the drum spindle and the supply tank. The inventor claimed that by first creating a vacuum in the tube the formation of undesirable air bubbles therein, which would have impaired the insulating properties of the paraffin wax, was avoided. In order to provide for contraction of the wax on cooling, steps were taken to cool the cable gradually in the direction of its length, by drawing it slowly through a cooling tank after first closing the open end. It was claimed that, by thus cooling the cable gradually along its length, air spaces left by contraction of the wax at the part cooled were immediately filled up by the still liquid wax in that part of the tube beyond it, the temperature of the cable being maintained throughout until it had passed into the cooling tank. The object was to produce a perfectly solid cable. The specification provided for sections of cable so manufactured to be jointed together to form a suitable length; the wires were to be jointed and insulated, an enclosing lead sleeve was soldered into position to bridge the gap in the lead sheath, and the joint filled with melted wax through an orifice left in the sleeve for that purpose. The inventor also contrived arrangements for a continuous process by jointing successive lengths together at the time of manufacture.

Marshall thus provided for his insulated conductors to be drawn into comparatively short lengths of lead pipe and afterwards impregnated with the filling material; also for several sections to be jointed together to form a suitable length, in spite of the fact that, 24 years earlier, Messrs. Young and McNair devised a method by which it was intended that cables might be manufactured in any convenient length and the impregnation and lead sheathing carried out as a continuous process.

Mention of an early cable experiment made in this country

as far back as 1880 may here prove of interest. Mr. David Brooks, of Philadelphia, evolved a system of underground work employing mineral oil as insulating material, applied to conductors of No. 18 S.W.G. tinned copper wires, covered with manilla, stranded into a cable, and contained in a wrought iron pipe.

The site of the experiment was the London and South-Western Railway Company's line between Westminster Bridge Road and Clapham Junction. The work was placed in the hands of the Silvertown Gutta Percha Company, and was carried out under the direction of Mr. Brooks. Thirty wires were to be provided between Westminster Bridge Road and Queen's Road, and 40 wires thence to Clapham Junction. Before being drawn into the pipe the formed cable was immersed in oil, raised to a temperature of about 300° F., in order to expel moisture and air. The joints were made in special T-pieces screwed on to the main pipe. The cable was terminated by a tail-piece of wires insulated with vulcanised india rubber and made solid with paraffin wax. At Westminster Bridge Road, a tank, situated at a level above the highest point reached by the line of pipe, was connected and the whole system was charged with oil, the supply being permanently maintained by the oil contained in the reservoir. Steps taken to remedy the considerable trouble experienced by leakage of oil at the pipe joints—no doubt due to vibration from passing trains—were not effectual. With certain modifications, the cable continued in use until 1889, when it was replaced by a new route of gutta percha-insulated wires. The system was installed for telegraph service, but telephonically is interesting because, during a portion of its life, some of the wires were employed for telephone purposes.

Similar systems had been installed by Mr. Brooks in America, where his method was for some time extensively used, for both telegraph and telephone purposes, mainly for the crossing of bridges, through tunnels, and actually under water in situations where the use of overhead wires was impracticable.

Mr. W. R. Patterson, of the Western Electric Manufacturing Company, played an important part in the production and development of the dry core cable. The Western Electric Manufacturing Company acquired the patent rights to make the Brooks cable, and Mr. Patterson was deputed to act under Mr. Brooks' direction. In an article, entitled, " Cables and Cable Making, Some Stray-

Recollections," published in the *Western Electric News* for July 1915, Mr. Patterson tells of his experiences with the Brooks system, and relates how on one occasion the reservoir was filled with water instead of oil, with results which may be imagined. He also tells of what he terms the first dry-core cable, laid on the Eads Bridge at St. Louis in 1880 or 1881. It appears that a cable was to be laid on the Brooks system, and Mr. Patterson, who was never enamoured with the use of oil, owing to the great difficulty of preventing leakage, particularly at the termination of the pipe, was in charge. The pipes were laid and carefully tested, after special precautions had been taken to render the joints tight, the core was drawn in and the oil delivered on site. Mr. Patterson goes on to relate in humorous vein how he remained behind accompanied only by a trustworthy assistant " to make some final tests." They " disconnected the reservoir, put a blind washer in the union, screwed it up again, filled the reservoir with oil and poured the rest into the river. The reservoir never required filling, not a drop of oil leaked out anywhere and they were glad to have one ' oil ' cable that required no attention."

Mr. Patterson was apparently never at any time an advocate of the filled or impregnated cable, but, to use his own words, " It would have been as easy to sell a cable filled with air as to sell a sausage filled with air. So it was necessary to find a filler."

Consequently in 1881 Patterson introduced in America a cable very much on the lines of the cable invented and patented in this country as long ago as 1869 by W. A. Marshall, already referred to, but with this difference, that whereas Marshall's cable was thoroughly impregnated with paraffin wax, Patterson, in order to avoid the rigidity inseparable from the solidity of Marshall's cable, and the consequent tendency of the lead sheath to rupture during process of handling (and probably also for economical reasons), charged the insulating compound with gas of suitable composition. A further reason for this process was to overcome the objection of the partial vacuum formed within the sheath by contraction of the impregnating material on cooling.

With these cables a lead-tin sheath was employed in the form of piping, in lengths of from 75 to 100 feet; into these, after being well dried and treated with paraffin, the cable core was drawn. The ingenious method adopted by Marshall was utilised in threading these lengths of lead piping with the string employed

indirectly for hauling through the cable core. By means of a suction pump a small wad of cotton with stout string attached was drawn through the piping. The separate sections of sheathing were plumbed together in the ordinary way after the cable core had been drawn in, and the gas-impregnated paraffin was introduced under pressure, the whole cable length being maintained at a suitable temperature of from 200–220° F., in an oven.

In the first Patterson cables, the wires were cotton- or jute-covered, paper displacing cotton at a later period.

Patterson cable was protected by U.S. Patent 248209, of October 11th, 1881; the application was filed on May 14th, 1881, and experimental lengths were immediately made and used for aërial work. The first underground Patterson cable was laid through Washington Tunnel in 1882 and thereafter, until the dry-core cable was introduced, Patterson cable was used extensively in America. Sizes at first ranged from 10 to 52 pairs of No. 18 B. and S. (about 25 lb. per mile) conductor. No. 19 B. & S. (corresponding approximately to 20 lb. per mile), was adopted as standard gauge in 1891 for comparatively short circuits, and No. 16 B. & S., in 1889, as standard gauge for cables carrying long-distance circuits.

In 1882, a 75 pair Patterson aërial cable was erected in Chicago, and between that date and 1893 cables accommodating as many as 300 pairs of wires were produced.

The first Patterson cable to be used in this country was prior to 1882; a length of 1050 feet of 50 double-conductor, No. 26 B. & S. cable was included in a list of Patterson aërial and underground cables, actually in use at that date, referred to by Mr. J. E. Kingsbury on page 257 of his book, "The Telephone and Telephone Exchanges." It is believed this cable was supplied to and used aërially by the London and Globe Telephone Company in London.

In 1885, Birkenhead was telephonically connected with Liverpool by means of a cable laid through the newly-opened Mersey Tunnel. The cable was an anti-induction lead-covered cable containing cotton-covered wires, the cotton being saturated with resin oil. Three of the wires were earth connected at each end with the object of minimising the possibility of inductive overhearing. It was laid by the Lancashire and Cheshire Telephonic Exchange Co., Ltd.

The Fortin-Hermann type of cable should also receive mention, although it entered but little into practical commercial use in this country. This cable consisted of four rotated copper conductors upon which were threaded small cylinders or beads of wood treated with paraffin, the whole enclosed in a lead sheath. This class of cable was used somewhat extensively for underground work in Paris, and was accommodated largely in the sewers. Cable of this type was utilised for the Paris end of the Paris-Brussels telephone line opened for service on February 24th, 1887. Some Fortin-Hermann cable was laid in the Thames Embankment subway between Blackfriars and Westminster.

Another type of cable used to a limited extent in this country in about 1886 was manufactured by John Fowler and Co. of Leeds. It consisted of copper wires wrapped with cotton and insulated with a compound containing resin as the principal constituent, and encased in lead. These cables were lead sheathed by a patent process employing hydraulic machinery. It was stated that they were made in sizes ranging from 10 to 100 wires.

At this time the preservation of the lead sheath underground was looked upon as a matter of some doubt and fears were entertained that the chemical action to which unprotected lead sheath would be exposed would be sufficient to render it unreliable.

A type of cable extensively used for underground telephone circuits in many parts of the world, including this country, prior to the introduction of the dry-core cable in 1890, was that commonly but erroneously known here as the bituminous cable. It was a lead-covered cable containing wires cotton covered, twisted, stranded and braided, and permeated with a heavy distillate of petroleum, which rendered the cable solid. The lead sheath was finally served with a treated braiding for its protection against corrosion. It gave very satisfactory results when laid, but was somewhat difficult to handle. Not only was the weight of the cable increased by the presence of the impregnating material, but it was rendered very much the reverse of pliable and, during the process of laying, injury to the lead sheath was difficult to avert owing to its tendency to buckle. Difficulty was also experienced in cable hauling operations, through the pipe becoming obstructed owing to the tendency exhibited by the outer braiding to rip, and become detached from the lead sheath. Moreover, jointing operations were of a

dirty character, the sticky compound adhering to the hands and impeding the work. For this reason, the name by which this class of cable was commonly known to workmen was "string and treacle."

This type of cable was manufactured by the Fowler Waring Cable Company at North Woolwich, and was an attempt to circumvent the Patterson patent.

Waring, or so-called bituminous cable, was used in this country in preference to Patterson cable. According to Mr. Kingsbury, it was first described in a circular, issued in 1887 by the Standard Underground Cable Company, who then claimed that it had been developed and applied during the past 5 years.

Lead press covering of cables was invented, as described, so far back as 1845 by William Young and Archibald McNair above mentioned, and was covered by British Patent No. 10799, of August 4th, 1845. The process was first publicly demonstrated at the London 1851 Exhibition. It was first used for power cables, but in 1879 Berthoud and Borel, of Switzerland, adopted it for sheathing multicore telegraph cables. It was adopted at an early date by the Standard Underground Cable Company for Waring cable and by the Western Electric Manufacturing Company for Patterson cable, but, as related, Patterson cables were, up to 1882, drawn into lead pipes supplied in lengths of 75 to 100 feet.

CHAPTER IX

THE NATIONAL TELEPHONE COMPANY, LIMITED, IN THE PROVINCES, 1884–1912

It has already been related how, in order to establish the telephone business as quickly as possible in the principal towns of the United Kingdom, the United Telephone Company adopted the policy of licensing subsidiary companies to institute telephone service throughout the provinces, reserving to itself the territory in and around the Metropolis. The expansion of the local service and rapid development of trunk lines which ensued after the new indentures of 1884 had been entered into involved communication between systems owned and worked by the different companies and introduced difficulties in administration and handling of traffic which gave promise of becoming almost unmanageable under the conditions existing.

The telephone was now well established, and was flourishing; not only were the difficulties of administering trunk traffic between the different systems increasing in their complexity, but for other reasons it appeared to be high time that steps should be taken to bring the telephone service of the country under unified direction and management. Consequently, in April 1889 consideration was given to the desirability of joining forces by amalgamation of the separate administrations.

Everything seemed to point towards the advisability of the adoption of this course; not only was the date of expiry of the master patents approaching (Edison patent July 30th, 1891, Bell patent December 9th, 1890), but certain rumours of projected competition were already current whereby opposition service, at a rate lower than that charged by the existing companies, was likely to be attempted. There were also certain obvious economic advantages to be secured by amalgamation. Other reasons were also advanced for the decision ultimately arrived at to form an entirely new company for the purpose of absorbing the businesses of those which already existed.

It was proposed that the companies should amalgamate under the title of "Telephone Union," and this course was definitely shaped, but the Government objected to the proposal on the grounds that such a combination was never anticipated when the respective licences which did not provide for such a contingency were granted, and declined to issue to the proposed new company the requisite licence or to permit the assignment of a licence already in possession of one of the companies concerned.

The difficulty was overcome by what was no other than a subterfuge. Instead of forming a new company, as was originally intended, it was arranged that one of the three principal companies should absorb the other two and as they were in possession of licences, any one of them competent to cover the business of all three companies when united, it was, from that point of view, immaterial which of the three companies should continue in operation and which two of the three should retire. It seemed to be fitting that the United Company, being the parent company, should absorb the Lancashire and Cheshire and National Telephone companies, but the latter company, its shares being nearer to par in market price than those of the other two, was eventually selected as the one which should continue in existence and therefore on May 1st, 1889, the three principal companies, the United, Lancashire and Cheshire, and National companies amalgamated. The title National Telephone Company was retained, the other two names receding into past history at this date; as a generous development was anticipated to result from the accelerated activities contemplated, the capital was increased to £4,000,000.

At the time of the amalgamation, the National Telephone Company had in all 10,813 exchange and private lines associated with its system, the United Company 6,793 lines and the Lancashire and Cheshire Company 5,979 lines, a total of 23,585 lines.

Mr. James Brand, previously Chairman of the board of directors of the United Telephone Company, to whom it was largely due that the telephone was so vigorously taken up in this country, relinquished that office in favour of Mr. Frederick R. Leyland, a former director of the United and National companies, who thus became first president of the newly-constituted board of the National Telephone Co., Ltd. The vice-presidents were

Mr. James Staats Forbes and Colonel Robert Raynsford Jackson. The ten directors were as named below :—

Chas. Swain Agnew,	Dillwyn Parrish,
J. W. Batten,	W. Cuthbert Quilter, M.P.,
John Bruce,	George Hunter Robinson,
Peter Garnett,	Samuel Herrick Sands,
Eli Heyworth,	Ald. Joseph Thompson.

In the report of the directors for the year ending April 30th, 1890, capital account was debited with two amounts representing the cost of purchase of the two undertakings, the United Telephone Company, Ltd., and the Lancashire and Cheshire Telephonic Exchange Co., Ltd., which were respectively £957,144 15*s.* 2*d.* and £615,177 3*s.* 9*d.* The result of the first year's working of the combination was a net increase of 4122 lines, a growth at the rate of 17·5 per cent. during the year.

The National Telephone Co., Ltd., continued to operate under the indenture previously issued to them dated November 29th, 1884, which gave to them authority to administer a public telephone service and to receive payment therefor, during a term of 31 years from January 1st, 1881, so that in the normal course of things, unless determined by purchase of the system at an earlier date in accordance with the terms of the agreement, their licence would expire on December 31, 1911.

The policy of amalgamation was continued, and the Northern District Telephone Company, with its working lines numbering 1551, and the South of England Telephone Company, with 3235 lines, were absorbed by the National Telephone Company on April 30th and October 31st, 1890, respectively. The cost of these two undertakings was debited against capital account in the financial statement, accompanying the report of the Directors for the year ending April 30th, 1891; the purchase price of the Northern District Company's undertaking was £80,942 15*s.* 0*d.* and that of the South of England Company £150,452 6*s.* 7*d.*

In the latter part of 1889, "Co-operative Telephony" began to be talked of, and on December 5th, 1889, a meeting was held in the Memorial Hall, Manchester, to ventilate the subject. It was explained to the meeting by Mr. A. D. Provand, M.P., that the idea was to form a new company to be floated on what might be called co-operative or mutual principles. He gave as reason

why the prevailing high rate of £20 was charged the enormous capital created by the telephone companies. The company had created four times the capital and charged four times the price it ought to have done. The Bell patent expired on December 9th, 1890. He (Mr. Provand) had letters showing that the Postmaster-General would grant a licence as soon as the proposed association was formed. A yearly subscription of £5 was suggested. The capital required was stated to be £12,000 and the cost of maintenance £6000 per annum, estimated on a basis of 1500 subscribers.

On December 23rd, 1889, a further meeting was held to consider the report of the committee previously appointed to deal with the question. It was announced that conditional undertakings had been received from 1300 potential subscribers, and that 500 private telephones had been applied for. The number of subscribers assumed for estimating purposes was 1500, but in view of the rental not exceeding £5, 4000 to 5000 were expected. An estimated capital outlay of £12 per subscriber's line was mentioned, and compared with the existing company's capital outlay per subscriber of £112 as exhibited by the last report and accounts of the Lancashire and Cheshire Company. It was recommended that a company be formed, and a committee was appointed to carry into effect the recommendation of the report.

The promoters were afterwards warned in the technical Press that although it was generally agreed that the rate of £20 then in force was too high, a scheme based on a cost per subscriber's line of no more than £12 was financially unsound.

The principal telephone patents in force, owned by the National Telephone Company, were due to expire as follows :—

Graham Bell's receiver, December 9th, 1890.
Edison's transmitter, July 30th, 1891.
Hunnings' transmitter, September 16th, 1892.
Blake's transmitter, January 20th, 1893.
Crossley's compound microphone, February 1st, 1893.

The fact that these patents were shortly due to terminate, the dissatisfaction freely expressed against the high rates still charged by the telephone companies in 1889, the threats and rumours of competition common at that time and the economies effected as

a result of the amalgamation of the three chief companies, led to consideration by the companies of the desirability of lowering their charges. On May 1st, 1890, therefore, the rates in Manchester, Liverpool, Warrington, Leeds and other towns were reduced from £20 to £15 and on January 1st, 1891, when the amalgamation of five of the companies had been completed, a further and universal reduction of rates to £10 followed throughout the whole of the country.

The trunk charges were also modified at the same time. At a later date it was announced by Mr. James Staats Forbes, the president of the company, that the decrease in revenue involved in these reductions amounted to £55,000 per annum.

The Post Office rates were also modified at about the same time and for exchange service became as follows :—

Within ¼ mile	£8	per annum.
,, ½ ,,	£10	,,
,, ¾ ,,	£12	,,
,, 1 ,,	£14	,,

The association of the three principal companies in May 1889 did not have the effect of preventing the competition which had been advertised and discussed, for the action taken in Manchester culminated in the formation of a company, for the purpose of competing with the National Telephone Company in that city, and other parts of the County of Lancashire. This company, floated on February 4th, 1890, under the title of "The Mutual Telephone Co.," commenced operations in Manchester with a capital of £100,000.

A tariff of £6 was decided upon, an inducement to take up shares being offered in the form of a rebate on the telephone rental which, for shareholders, became £5. A licence was granted by the Postmaster-General on May 9th, 1890, and an exchange was opened in Manchester on February 28th, 1891.

No intercommunication between the rival systems was arranged for, and therefore, in order to secure communication with the whole of the subscribers connected to the exchanges of the two administrations, it was necessary to subscribe to both.

The Mutual Company intended to establish telephone service in Liverpool, but met with such strenuous opposition, largely engineered by or on behalf of the National Telephone Company, that little progress was made, and the project of opening an

exchange in Liverpool was therefore ultimately abandoned. A competitive service was, however, instituted in Bolton.

The system of working adopted by the Mutual Telephone Company of Manchester was the subject of a patent, No. 19486, by Mr. Alfred Rosling Bennett, of 26 Booth Street, Manchester, the company's chief engineer. The provisional specification was dated November 27th, 1890, and the complete specification August 18th, 1891. No provision was made in the patent specification for signalling devices as the arrangement was designed primarily for use in conjunction with the Mann or Law Call-wire system, in which such devices were dispensed with. The multiple was flat or horizontal, and comprised a series of double plates of insulating material, each 5 inches square, arranged one below the other. Each plate was pierced with one hundred holes in which brass ferrules, sockets or bushes were fitted, the ferrules in the under-plate being smaller in diameter than those in the upper. The plates were rigidly attached with a separating distance of about half an inch. The sockets constituted the multiple connections, and a pair of sockets was reserved for each metallic circuit on each section of the switch-board, one wire being connected to the larger or upper socket and the other to the corresponding smaller socket of the lower plate.

Five rows of ten squares each, representing 5000 metallic circuits, were considered to represent the convenient reach of an operator. The subscribers' lines were multipled every tenth square, the multiple cables being accommodated in a recess beneath the horizontal plane formed by the ebonite squares fitted with sockets.

Connection between one subscriber and another was established through the multiple socket contacts, by means of a two way flexible cord terminated at each end by means of plugs of unusual design and illustrated in Fig. 70. The extremity of the plug was in the form of a pin intended to engage and make contact with the undermost bush; the sleeve of the plug connected with the uppermost bush, and firm contact was promoted by means of a shoulder attached to the sleeve of the plug by a small spiral spring brought under compression when the plug was inserted. The cords and plugs were accommodated in a canopy suspended above the table-like multiple field in a manner somewhat similar to that illustrated in Figs. 85 and 91.

A diagram giving the main features of the system, including the engaged test device, appears in Fig. 70, and in the same illustration details of a block of multiple sockets is given. One of these blocks is preserved in the museum of the Institution

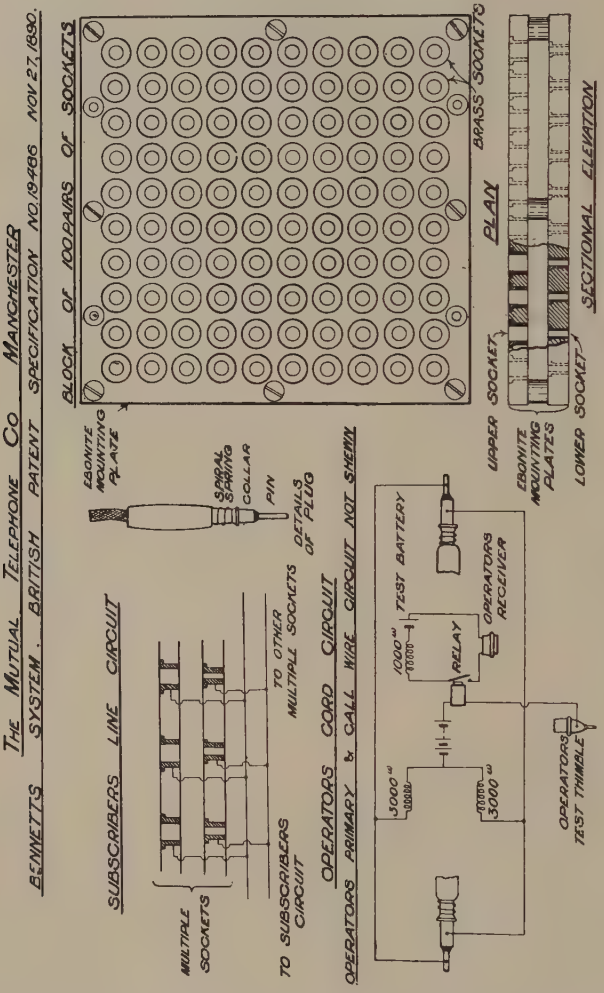

Fig. 70.—Mutual Telephone Company's Exchange System, Manchester, 1890.

of Electrical Engineers, and another at the Science Museum, South Kensington.

Johnson transmitters as well as transmitters of the granular type were used in the subscribers' instruments employed.

The method of working adopted by the Mutual Company is

briefly described in the second edition (1895) of the "Practical Telephone Handbook," by Joseph Poole. Mr. Poole was chief electrician to the New Telephone Company, which company ultimately acquired the Mutual Company's undertaking.

On January 1st, 1892, the Mutual Company sold its business and licence to the Electric and General Investment Co., Ltd., who transferred it to the Pioneer Telephone Co., Ltd., on February 26th of the same year. The story of how the Mutual Telephone Company's business, after its purchase from the Pioneer Telephone Company by the New Telephone Company passed into the hands of the National Telephone Company is told in Chapter X.

In continuation of the policy of amalgamation decided upon, the National Telephone Co., Ltd., on January 1st, 1892, absorbed the Western Counties and South Wales Company with their 4027 subscribers' lines, and in March of the same year the telephone plant and business of the Sheffield Telephone Exchange and Electric Light Company, with 1415 subscribers' lines, was acquired. By the end of the company's financial year, on April 30th, 1893, four other, but smaller, telephone companies were absorbed. Particulars of the six companies acquired by the National Company at this time are as follows :—

Name of Company purchased.	Date of purchase.	Purchase price.
		£ s. d.
Western Counties and South Wales Telephone Co., Ltd.	Jan. 1st, 1892	277,607 13 8
Sheffield Telephone Exchange and Electric Light Co., Ltd.	March 1892	38,696 14 4
*Caledonian Telephone Co.	April 1892	4,235 17 0
*Universal Telephone Co.	May 1892	3,200 5 0
Isle of Man Telephone Co.	October 1892	1,935 17 3
Thanet Telephone Co.	February 1893	20,100 0 0
		£345,776 7 3

* These were small private wire businesses.

The consolidation of the telephone companies of the United Kingdom thus proceeded gradually and was ultimately completed with the acquisition of the Telephone Company of Ireland, Ltd., with 1530 lines, at a purchase price of £98,390 6*s.* 3*d.*, in January 1893, and the Home Telephone Co., Ltd., a small private

wire business in London, at a cost of £2648 19*s.* 9*d.*, in April 1894.

As the companies were absorbed the indentures they held were surrendered. The acquisition of the smaller companies by the National Telephone Company was hastened by the fact that the heads of arrangement entered into between the Post Office and the National Company, on August 11th, 1892, for purchase of the trunk line system by the Post Office, a transaction referred to at greater length in Chapters XVIII and XXI, placed the company under obligation to procure the surrender of some ten licences, embracing the whole of the country, granted to other concerns. The company was placed at some disadvantage by this arrangement. In one case, namely, that of the Thanet Telephone Company, a purchase price of as much as £20,100 had to be paid in respect of that company's only effective asset, a private telephone line between Margate and Ramsgate, a distance of but five miles approximately.

The only competitor the company now had was the Post Office. The policy adopted by the Post Office at this time did not, however, involve active competition to the operations of the company, except in the cases of Newcastle-upon-Tyne and Cardiff and immediate neighbourhoods, and even in these two places the Post Office did not seriously set itself to build up competitive systems. By the end of 1894, therefore, the business of providing exchange telephone service was entirely in the hands of the National Telephone Co., Ltd., excepting the comparatively small telephone service worked by the Post Office and dealt with separately in Chapter V.

At December 31st, 1894, the number of exchange and private lines worked by the National Telephone Company was 73,353.

It is somewhat difficult to compose an orderly and connected story including in its purview all the affairs and activities of the company from this time (1894) onwards, and in view of the diverse nature and extensive scope of the various functions of the company in their dispensation of telephone service the author has deemed it desirable to devote separate chapters to the treatment of technical matters and engineering details in which the company as well as others were concerned.

Legislation has exercised a most important influence upon the telephone service of the country, and throughout its life the

company was subject to control by legislation. Chapter XXI has been set apart, therefore, solely for the consideration of legislation, in so far as the telephone was concerned, and to its application in regulating the activities of the National Telephone Company, as well as other telephone administrations.

The remainder of the present chapter will consequently be confined principally to the consideration of those features of the company's operations which do not fall naturally under one or other of the particular sections dealt with in other chapters, and will deal largely with the managerial and administrative side of the company's business.

Until the assimilation of the subsidiary telephone companies under the single title "National Telephone Company" was completed, it was not possible for any very serious move to be made towards the desirable establishment of a control operating at one common centre and under one common head. The general managers of the subsidiary companies were retained, and carried on their respective businesses in a similar capacity for the National Telephone Company, controlling the same staff, operating over the same territory, but co-operating more fully with their neighbours, and, to a large extent, exercising their individuality in both managerial and technical matters.

It was, however, essential that, as soon as possible, uniform methods of management, of accounting and of engineering practice should be introduced throughout the whole country and that a central controlling body should be established effectively to direct the policy and affairs of the company. Consequently, in March 1892 a general manager for the country, with offices at Oxford Court, Cannon Street, London, E.C., was appointed; Mr. William Edward Louis Gaine, a solicitor, formerly Town Clerk of Blackburn, accepted the position, and a head office staff was gathered together for administration of the company's business on uniform lines.

The necessity for high grade engineering work, and the importance of the functions of the telephone engineer in the provision of high class telephone service, were not at that time fully recognised. The business was, however, rapidly growing and, in consideration of the amalgamation of all the telephone companies, its dimensions were becoming such that unified administration and organisation were essential to success in engineering methods,

as well as in commercial management. Therefore as a first step towards the desirable unification of engineering practice, three months after the appointment of a general manager for the country, viz., in June 1892, the office of engineer-in-chief was created, and Mr. Dane Sinclair, at that time manager for the London area, was appointed to the position.

Mr. Dane Sinclair was the patentee of the first automatic telephone system, referred to in a later chapter, brought into practical operation in this country. His name figures prominently in the records of the British Patent Office in connection with telephone inventions, frequently in association with that of W. Aitken, a prolific inventor of telephone switching systems and devices.

By the end of 1893 considerable progress had been made in the reconstitution of the several systems of management previously built up by the separate companies. The territories formerly worked by the subsidiary companies were, with some adjustment, retained under the management of the same general managers, who became superintendents acting immediately under the direction of the general manager.

In course of time the areas of management became eight in number. These areas, with the names of the respective superintendents most closely associated with them are given in Table 3.

The names of most of those mentioned will be familiar to many telephone engineers. Many of them became interested in telephony immediately upon its institution as a business concern in the locality against which their names appear and they are therefore to be numbered amongst the pioneers of the telephone service in this country.

Each of the eight provinces was divided into districts, and over each district a district manager was appointed to take charge. The organisation and control of each district were arranged generally on the lines indicated by the diagram shown in Fig. 71.

The varying practices which obtained under the old *régime* were abolished as far as possible, and universal methods of accounting and managerial and engineering practice were introduced. By 1895 fairly settled methods were in force throughout the country.

NATIONAL TELEPHONE CO., LTD.

Typical District Organisation, 1893–1903.

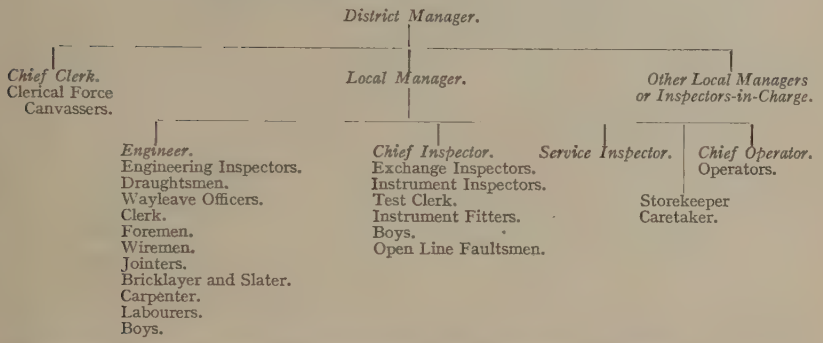

FIG. 71.—Typical District Organisation, the National Telephone Co., Ltd., 1893–1903.

With few exceptions, the first telephone line systems were of single wire with earth return. The exceptions were, first the Post Office, which from the outset consistently erected metallic circuit lines for local exchange as well as trunk service, and, secondly, the Northern District Telephone Company, which adopted a metallic circuit line system generally, although not in Sunderland. Probably the Northern District Company was influenced by the fact that the Post Office, their competitor in Newcastle and the immediate surrounding towns, adopted a metallic line system from the first. The exception of Sunderland was probably accounted for by the fact that the number of subscribers in Sunderland at the time they acquired the undertaking had already reached such a figure that to metallicise their lines would have involved the company in a work of some considerable magnitude and difficulty and an expenditure which, at that time, they were not prepared to undertake and consequently the single wire system was retained and extended.

The London and Globe Telephone and Maintenance Company also adopted a metallic line system, which has been described, but as this company did not operate for a period longer than about four years and as they possessed only one exchange which disappeared on acquirement of the system by the United Company, the effect was not very material.

Nowadays an exchange telephone system with earth return is entirely out of the question, but the early telephone engineers

appear to have had good reasons for the policy which they adopted of installing single lines. Telegraphs were operated with earth return, and there appeared to be no reason why earth return telephone lines should not work with equal success. Electric light and power distribution was but in its early infancy and no disturbing effects were noticeable, the line accommodation requisite for a metallic circuit was double that for a single wire, a most important consideration in the days of open wires over housetops, and, last, but not least, the capital outlay involved in the provision of a metallic circuit was greatly in excess of that for a single wire, and capital was at first scarce and difficult to obtain. It was, however, in the natural order of things that the single earth circuit lines which continued to be used for some fifteen years after the telephone was introduced should ultimately be metallic circuited. There were several reasons why this should be so. In the days of the Blake transmitter, although overhearing was common and lines were far from noiseless, they were nevertheless workable, but with the more efficient granular transmitter, which replaced the Blake, overhearing was so great as to render satisfactory conversation almost impossible; in fact, in certain cases, granular transmitters fitted in association with single lines had to be removed, so great was the disturbance caused on other neighbouring lines in comparison with that due to the Blake instruments which previously existed.

The company's single wire system, as they found to their cost, was particularly susceptible to external disturbing electrical influence and the introduction of electric lighting and traction, which rapidly extended all over the country, caused no little trouble to the telephone service in various places.

The telephone companies quickly took action for the protection of their interests with the object of compelling undertakers of electric power systems to take such steps as would obviate interference with their telephone service. They commenced by offering opposition to the Bills presented for the establishment of electrical tramway undertakings. There were two chief considerations, interference with telephone conversations by induction and the endangering of the company's plant by tramway mains running in proximity to telephone lines.

Opposition to tramway undertakings was first taken at Weston-super-Mare and at Wellingborough, the promoters being com-

pelled to bear the expense of protecting the then existing lines of the South of England Telephone Company.

In the Birkenhead Electric Lighting Provisional Order Bill in July 1890, a clause was inserted which obliged the undertakers to construct and work their entire system in such a manner as not injuriously to affect existing or future telephone circuits.

The rapid extension of electrical power systems led to action being taken by telephone companies in opposing not far short of fifty Parliamentary Bills in order that clauses for their protection might be inserted. The essentials of such clauses were generally as follows, taken from the case of Plymouth 1890 :—

" The Company shall so construct their electric circuits and other works of all descriptions, and shall so work their tramways in all respects as to prevent any injurious interference by induction or otherwise with the electric circuits from time to time used or intended to be used by the Telephone Company, for the purpose of telephone communication, or with the currents in such circuits. Provided that as regards electric circuits erected or laid down by the Telephone Company after the construction of the works of the Company, this sub-section shall only apply if reasonable and proper precautions have been taken in the erection or laying down of such circuits and if they have not been erected or laid down in unreasonably close proximity to the lines or works of the Company."

On April 8th, 1892, the Western Counties and South Wales Telephone Company secured an order against the Bournemouth and District Electric Supply Company, who, it was claimed, had disturbed electrically by the operation of their system the telephone company's service in Bournemouth and neighbourhood; the order directed that the defendants be perpetually restrained from working or using their electrical system in such a manner as to injure or interfere with the plaintiffs' exchange system and in particular from causing or permitting injury to the plaintiffs' system by induction or leakage or from any other cause connected with the defendants' inductors.

The telephone companies continued to experience interference with the working of their telephones in various parts of the country, due to the introduction principally of electric traction, and in 1892, when electric street traction was introduced into Leeds, the disturbance was of such a serious nature that it led to an interesting action being tried by Mr. Justice Kekewich.

The case was brought by the National Telephone Company to restrain Mr. Graff Baker, the contractor for the Leeds Corporation Tramways, from so working his tramway as to occasion a nuisance to the plaintiffs' telephone lines and for damages.

The case commenced on December 13th, 1892, evidence being given by Dr. John Hopkinson and Messrs. Dane Sinclair, W. H. Preece and James Swinburne, and was adjourned in order that an independent expert might visit Leeds to examine into the alleged disturbances and submit a report.

Plaintiffs alleged that the effect of working the tramways was to interfere with and disturb plaintiffs' electric currents in their neighbourhood and to render wires owned or used by plaintiffs useless for telephonic communication and so constitute a nuisance, and that unless this nuisance was abated the business of the company in Leeds would be seriously damaged. It was claimed that electrical disturbance caused by defendants' system could be readily prevented by the adoption of a different method of completing the electric circuit from the cars to the generating station.

The Defendant alleged that the tramway had been constructed under statutory authority and pleaded agreement and consent of the Board of Trade under which he was working the tramway and denied alleged electrical disturbance. He contended that even if there was such a disturbance it did not infringe any right of the plaintiffs and could not be prevented by adoption of a different method of completing the electric circuit from cars to generating station. He claimed that plaintiffs could easily obviate such electrical disturbance by the adoption of some other method of completing their electric circuit than by the earth return adopted by them, and denied the alleged nuisance.

Judgment was delivered on February 4th, 1893. Mr. Justice Kekewich concluded that the interference was of a serious character as shown by the report of the independent expert, Mr. Macrory, and intimated that if actionable the remedy would probably be by injunction rather than by damages. The real and only question in the case was whether the interference was actionable. He cited the case of Fletcher *v.* Rylands, and stated that he could not see his way to hold that a man who has created, or if that be inaccurate, called into special existence, an electric current for his own purposes and who discharges it into the ground

for his own purposes and beyond his control is not as responsible for damage which that current does as he would have been if, instead, he had discharged a stream of water (*vide* the case of Fletcher *v.* Rylands). The defendants claimed, however, that they were acting under statutory powers, derived from a Provisional Order confirmed by Act of Parliament and that if in the proper exercise of those powers they injured the plaintiffs they were free from blame. The defendants' plea was good in law and they were not responsible to the plaintiffs for the mischief caused by their works.

They were expressly authorised to use electrical power, and the Legislature must be taken to have contemplated it and to have condoned by anticipation any mischief arising from the use of such power. The conclusion from the evidence was that defendants' system was on the whole the best which practical science had yet discovered, but at least as good as any other. It was held that plaintiffs could not maintain an action either for an injunction or damages, and they were ordered to pay the costs.

On April 26th, 1893, a meeting was held at the Board of Trade, Sir Courtenay Boyle presiding, at which the telephone company and the Electrical Traction Association were represented. The Telephone Company submitted that inasmuch as they had opposed some fifty Bills in Parliament in order to secure the insertion of clauses for the protection of their interests the time had now arrived when the Board of Trade should accept one of those clauses as a model clause and take measures to secure its insertion in all Electrical Traction Bills and Orders without further action of the company.

Subsequently, a resolution was passed by Parliament for the appointment of a Joint Committee of Lords and Commons

> "To consider and report whether the grant of statutory powers to use electricity ought to be qualified by any prohibition or restriction as to earth return circuits or by any provisions as to leakage, induction or similar matters, and if so in what cases and under what conditions; and if the Joint Committeee are of opinion that any such prohibition, restriction or provision should be enforced, to settle the necessary clauses."

The question developed into a battle royal in which the Municipal Corporations Association, the London County Council,

the Electrical Traction Association and other bodies were all ranged against the National Telephone Company. The company was accused of attacking the whole electrical industry of the country, not because its telephonic monopoly was threatened, but in order to mask the imperfections of its single wire system and the question raised a considerable amount of interest and comment in the technical Press.

The Joint Committee appointed by Parliament commenced its sittings on June 19th, 1893, and its deliberations extended over a period of nine days.

Evidence was taken from Sir Courtenay Boyle, Mr. W. H. Preece, Engineer-in-Chief and Electrician to the Post Office, and Major Cardew, Electrical Adviser to the Board of Trade and the Astronomer Royal. Counsel appeared on behalf of : The National Telephone Company, the Railway Companies, Electric Tramway Companies and Electrical Underground Railway Companies, Electric Lighting Companies, Municipal Corporations of England and Scotland, the Tramway Institute of Great Britain and Ireland and Gas and Water Companies. Her Majesty's Postmaster-General was also represented.

A clause for insertion in all Bills and Provisional Orders which authorised the undertakers other than electric lighting undertakers to use large currents was agreed upon.

The salient part of Section 5 of this clause provided that :

" The Undertakers shall take all reasonable and proper precautions in constructing, placing and maintaining their electric lines, circuits and other works of any description, and in using their electric lines, circuits and other works, so as not injuriously to interfere with the working of any wire, line or apparatus from time to time used for the purpose of transmitting electric power or of telegraphic, telephonic or electric signalling communication or the currents in such wire, line or apparatus. Provided always that the Undertakers shall be deemed to take all such reasonable and proper precautions as aforesaid if and so long as they adopt and employ, at the option of the Undertakers, either such insulated returns or such uninsulated metallic returns of low resistance, and such other means of preventing injurious interference with the electric wires, lines and apparatus of other parties, and the currents therein as the Board of Trade shall direct, and in giving such directions the Board shall have regard to the expense involved and to the effect thereof upon the commercial prospects of the Undertaking.

" Provided also that at the expiration of . . . . . years from the passing of this Act (Order) nothing in this sub-section shall operate to give any right of action in respect of or to protect any electric wires, lines or apparatus or the currents therein unless in the construction, erection, maintaining and working of such wires, lines and apparatus, all reasonable and proper precautions, including the use of an insulated return, have been taken to prevent injurious interference therewith, and with the currents therein, by or from other electric currents . . ."

Electric lighting companies were to be exempted from the operation of this clause.

The Committee also agreed upon certain resolutions in the nature of recommendations, chief of which may be stated briefly as follows :—

(1) It was not in the interest of the public to insist upon electrical tramways using an insulated return conductor.
(2) In order to overcome interference by leakage and induction, the provision of an insulated return conductor for telephones was recommended as the best known means of overcoming such disturbances.
(3) Disturbance to railway signal communications should be obviated in a similar manner, *i.e.* by the adoption by railway companies of an insulated metallic return.
(4) Statutory powers should be granted enabling telephone undertakers to lay their wires underground and facilitate the provision and use of the complete insulated metallic return.
(5) Improved methods of construction of electric railways would reduce the danger from fusion or electrolytic action.
(6) The Board of Trade should make regulations to secure the best system of working electric railways and tramways.

The Committee's findings were considered generally to be a victory for electric traction, and such as would tend towards an improvement in telephone working, and the telephone company was in hopes that at last there was reasonable prospect they would be granted the statutory powers they desired in order to enable them to undertake the metallic circuiting of their systems throughout the country.

Board of Trade regulations for electric tramways were published in draft form in November 1893, and in the amended and final form, which differed but slightly from the draft, on March 6th, 1894.

From 1894 a very busy period set in for telephone engineers as, in addition to catering for normal development, the work of doubling all the earth circuit lines, a work of considerable magnitude, had to be undertaken. In places where reasonable wayleave facilities were available, opportunity was taken to augment and extend existing underground systems, and, in places previously fed by overhead means, to instal underground plant, not only to permit of the doubling of the existing lines, but also to provide suitably for prospective development. As a consequence, a large portion of the line plant in many important towns was remodelled and modernised and a considerable amount of overhead plant was taken down.

The metallic circuiting of Glasgow was undertaken in face of particular difficulties presented to the engineers concerned by reason of the fact that the National Telephone Company was unable to come to terms with the Glasgow Corporation in regard to the installation of underground plant. The work was therefore accomplished largely by means of overhead cables. The metallic circuiting of Glasgow was commenced in 1896 and completed in 1903.

One of the most serious difficulties the National Telephone Company, as well as their predecessors, had to contend with throughout the whole period of their licence was that of securing the necessary wayleave for the placing of their external plant. Their difficulties were by no means confined to the negotiation of consents with private property owners, but were experienced also in their dealings with highway authorities, with many of whom they were unable to come to terms considered acceptable, for the laying of underground plant in public thoroughfares, or even to negotiate agreements upon any terms whatsoever. The steadily growing number of subscribers rendered it increasingly difficult, and, in fact, highly undesirable from many aspects, to provide service in busy towns and industrial neighbourhoods without having recourse to underground cables. This was a most unfortunate circumstance, not only from the point of view of the telephone company, but also from that of the corporation

concerned; the telephone user also was deprived of the numerous advantages to be derived from the inclusion in his circuit, of a greater proportion of underground, and a corresponding diminution in overhead wire.

The chief reason why the National Telephone Company's system, at the time of its purchase by the State, included, in some places, such a large proportion of overhead plant was that the authorities controlling the public thoroughfares were considered unreasonable in the conditions they stipulated and the payments they demanded for facilities undoubtedly essential to the provision of an efficient telephone service.

It has previously been related how, on three occasions, the United Telephone Company sought Parliamentary powers to enable them to secure the wayleave facilities required in the interests of the telephone service, and how, on each occasion, their efforts were unavailing.

At about the time of the Amalgamation of the United, National and Lancashire and Cheshire companies, difficulties of some consequence arose in connection with the acquisition of wayleaves for the London-Birmingham trunk line, at that time in course of construction. The objections raised to the company's proposal to erect poles along public roads assumed serious proportions when the line was nearing London, where the Hendon Local Board raised objections to the erection of poles along the Edgware Road. The Hampstead Vestry took similar objections to the proposal to erect poles in their district and the consequence was that considerable delay occurred in the completion of the line.

Suggestions were made by the parties concerned that the telephone company should utilise private property, and also that they should seek to secure Parliamentary powers. The answer given at this time by Colonel Jackson, vice-chairman of the National Telephone Company, to a question as to why the company did not press for Parliamentary powers, was that his company was threatened with opposition by the Post Office, and that it was considered that the Post Office, backed up by the Ministers, would be too strong for them. Nevertheless, the National Telephone Company pursued the matter again very soon, for in 1891 a Parliamentary Bill asking for the required statutory powers was promoted. The fate of this Bill was as

unsatisfactory as that of the Bills which preceded it and is related in Chapter XXI.

In 1899, for the last time, Parliament was approached by the National Telephone Company for the purpose of securing to the company the wayleave powers considered necessary, and for the fifth time in the history of the telephone companies the application was unsuccessful.

It was particularly unfortunate that an agreement could not be arrived at between the company and the two most important public authorities in the country. In London as well as Glasgow the company failed in its attempt to make suitable arrangements for the installation of the needful underground plant, and the metallic circuiting of both these places was rendered particularly difficult, and had to be carried out for the most part without the aid of underground work.

In Glasgow, the company was blamed for inefficient service, but the facilities essential to an improvement were nevertheless withheld. The difficulty was aggravated by the fact that the Glasgow Corporation was the most anxious of any municipality to institute a telephone service of its own, and utilised its authority over the highways as a lever to induce the Postmaster-General to grant the licence desired.

The National Telephone Company was in some instances impelled to agree to conditions and terms of payment for facilities to lay underground plant which, for a service regarded largely as of a public character, were considered of a most onerous nature.

For example, an agreement entered into on May 24th, 1894, between the National Telephone Company and the Manchester Corporation contained the following provisions :—

(*a*) A payment was to be made by the company of 5*s*. for each subscriber connected to the Central Exchange, with a miminum payment in respect of 3000.

(*b*) A payment of 10*s*. per annum for each manhole, and 5*s*. per annum for each underground box was stipulated.

(*c*) Payment was to be made by the company at the rate of 5*s*. for each trunk line laid underground.

(*d*) The agreement might be determined by the Corporation serving upon the company six months' notice, and in the event of such notice being given, the company was under obligation to withdraw the underground wires laid under its provisions.

It was not until after completion of this agreement, that is, in the year 1895, that the company was enabled to take in hand a comprehensive scheme of underground work for Manchester, which provided for the conversion of the existing single lines into metallic circuits.

The precedent created by the company's acceptance of such conditions was an important one, as it resulted in somewhat similar terms being insisted upon in agreements afterwards negotiated with several other Corporations, amongst which was Liverpool on June 17th, 1896.

Some Corporations, however, adopted a broader and more generous policy in connection with the installation by the company of underground plant for telephone purposes, and, as a result, such towns benefited considerably in many ways. Not only was the normal telephone service improved and greater immunity from interruption to the service secured by a reduction in the proportion of overhead wire, but the amenities of their boroughs were preserved and the hundred and one objections which have been urged against the use of overhead wires were removed. In addition, the utility of the service was enhanced consequent upon the improved facilities afforded for development.

The amalgamation of the several telephone companies had not been brought to a conclusion before renewed representations were made to the Government advocating the early acquisition of the telephone service by the State, but in spite of frequent renewal of the recommendation, the Government persistently asserted its intention to permit the company to continue to operate until its licence terminated. The matter appears to have been brought to a head, however, by the promotion, in 1891, by the National and New Telephone companies of the Parliamentary Bills, previously referred to, for powers to enable the National Telephone Company to overcome the wayleave difficulties which assailed it on every side. As related in Chapter XXI, such strong opposition was offered to these Bills, chiefly by local and other public authorities directly interested, that Sir James Fergusson, the Postmaster-General, in opposing the Bills at the second reading on March 22nd, 1892, intimated his intention to bring in a Bill which would result in the acquisition of the trunk lines of communication by the State, in order to open up the way for the establishment of competitive service.

In proposing to acquire the trunk lines the Government was also influenced by the loss of telegraph revenue said to be due to the telephone trunk lines supplanting to some extent the telegraphs.

After some opposition the Telegraph Act of 1892, by which the trunk lines were acquired by the Post Office in 1896, was passed. The circumstances associated with the transfer of the trunk lines to the State are more fully considered in Chapters XVIII and XXI. The decision by the Government to acquire the trunk lines of communication built up by the company was a serious matter for the National Telephone Company and caused them no little perturbation. It opened the way for their potential competitors to compete effectively with them. They were powerless to resist by reason of the terms of the indenture which permitted them to conduct telephone business, and therefore they had to submit with the best grace they could muster. Under an agreement dated March 25th, 1896, entered into between the Postmaster-General and the company for purchase of the trunk lines, the company were, in future, to be restricted in their operations to certain telephone local areas. There were 213 of these areas defined in a schedule appended to the agreement, which made reference to a " verified map," indicating the whole of the areas geographically. The determination of these areas was a formidable task; each of them was initialled personally by Mr. (later Sir) John Cameron Lamb, C.B., C.M.G., Assistant Secretary to the Post Office and Mr. W. E. L. Gaine, General Manager of the National Telephone Company.

As in London (see Chapter X), so in Edinburgh and Glasgow, exception was taken by the Corporation to the Postmaster-General providing underground plant for the use of the National Telephone Company, under the provisions of the Telegraph Act of 1892. In December 1898 the Postmaster-General requested consent of the Glasgow Corporation to the placing of certain telegraphs underground, and in January the Corporation replied that they were prepared to give consent only on the understanding that it was not made applicable to the purpose of any private company or individual, whose application, if made to the Corporation, could be refused without right of appeal. In February 1899 the Postmaster-General intimated that he objected to this condition, and the matter was referred to the Sheriff, who, in April, decided that the condition should not be attached to the

consent, and granted the Postmaster-General the permission asked for. The Corporation expressed their dissatisfaction at this award, and the matter came before the Railway and Canal Commissioners at Edinburgh on July 11th, 1899. The case was concluded on the following day, when the Commissioners affirmed the Sheriff's judgment.

The agitation which continued after the passing of the Telegraph Act of 1892, principally engineered by local authorities, influenced largely by the Municipal Corporations Association, the London County Council and the Glasgow Corporation, is dealt with in Chapter XXI.

In that chapter particulars are also given of the appointment and proceedings of the Select Committee of 1895, the results of the Telephone Inquiry held in Glasgow in 1897, the appointment, deliberations and findings of the Select Committee of 1898 and the introduction, by Mr. Hanbury, of a Bill which ultimately became the Telegraph Act of 1899.

Mr. Albert Anns, in Part III of his series of articles in Volume VI of the *National Telephone Journal*, thus comments upon the proceedings of the Select Committee presided over by Mr. Hanbury, between the dates May 12th, 1898, and August 4th, 1898 :

> " Throughout the proceedings the chairman fostered an animus against the company, and instead of acknowledging the great benefits which it had conferred upon the community, sought to prove, but without success, that the National Telephone Company had from the beginning been indifferent and inimical to the wants and interests of the public. Even the responsible officials of the Post Office, who acknowledged having carried out in an honourable manner the understanding arrived at in 1892, were surprised and hurt by objectionable questions and insinuations."

The Telegraph Act of 1899 was the result of the continued agitation, which reached its zenith in 1898, against the National Telephone Company, the service it rendered and its alleged high charges. It was passed for the purpose of making requisite provision for inauguration, where desirable, of telephone service in opposition to the National Telephone Company. It provided, under certain conditions, for competition to be established with the company by the Post Office, municipal authorities, and

private companies who might be granted licences by the Postmaster-General.

Undoubtedly one of the principal factors which weighed with the Government in introducing legislation to permit municipalities to administer their own telephone service was the inability of the company to come to terms with many highway authorities for the installation of the underground plant which was essential in the interests of the telephone service of the country. This wayleave difficulty created an absolute deadlock in the telephone question. The National Telephone Company, realising the absolute necessity for metallic circuiting the whole of their system, were willing and anxious to lay underground plant, but numerous corporations either declined altogether to give their consent or imposed conditions the company were not disposed to accept.

The consternation aroused by and the opposition entered against Bills lodged from time to time by telephone companies for statutory powers was such as to deter any Government from proceeding to grant such powers. The Government hesitated to acquire the telephone system, as they were frequently urged to do, owing, no doubt, to the large amount of capital involved, the statements which were made regarding the watered state of the companies' capital, and their prior experience in the purchase of the telegraphs.

Consequently, as it was absolutely essential that something should be done to remove the deadlock which existed, and municipalities had evinced their determination to conduct their own local telephone exchange systems under the circumstances related in Chapters XIV and XXI, the Telegraph Act of 1899 was passed, which gave to municipalities their desire and deprived the company of the monopoly it was alleged they had abused.

The extent to which the National Telephone Company's system had grown up to December 31st, 1898, is illustrated by the following figures quoted from the directors' report for the half-year ending at that date :—

Number of towns and places supplied	794
Number of exchanges open	853
Number of lines	120,144
Number of telephone sets in use	146,044
Present ratio of effective calls per annum	272,917,048
Equivalent to (at least) messages	545,834,096
Average annual payment per line	£9 8*s.* 10*d.*
Average cost to subscriber per message	0.5 penny

At this time the authorised capital was £6,000,000, of which £5,669,471 had been issued.

The Telegraph Act, 1899, contained a clause to the effect that no person or body other than the recognised authority should be granted a licence in an exchange area already served by an existing company, unless it were shown that application for any such licence had the approval of the local authority.

The first licence to be issued by the Postmaster-General under the new Act was not to a municipality, as might have been expected, but to a private company, the New Mutual Telephone Co., Ltd., of Manchester. The City of Manchester had considered the question of municipal telephony early in 1896, and the New Mutual Company had been promoted towards the latter end of 1898, in anticipation of competition being authorised by the Government, and had been led to expect the support of the Manchester Corporation in obtaining the requisite licence. A licence was granted on December 30th, 1899, on receipt by the Postmaster-General of the stipulated resolutions passed by various local authorities in the neighbourhood of Manchester that they approved of the scheme, but the Manchester authorities had not by that time come to a definite conclusion as to the course they should pursue. The licence covered the borough of Salford and the urban districts of Moss Side, Wilmslow, Stretford, Audenshaw, Gorton, Altrincham, Sale and Swinton, and Pendlebury, but no part of Manchester.

Although originally the Manchester Corporation had as good as promised to lend their support to the scheme, the vacillations of the Council were such that the support anticipated by the New Mutual Company was never forthcoming and eventually the whole scheme was abandoned.

Another private company was promoted, under the title of the Norwich Mutual Telephone Company, for the purpose of competing with the National Telephone Company in Norwich, and on December 21st, 1900, an agreement was entered into with the Norwich Corporation, one of the conditions being that work should be completed within two years. A licence was granted to the company in June 1901, but in November 1903 application was made for an extension of time, on the ground that an agreement had been entered into with contractors to carry out the necessary work. The Norwich Corporation declined,

however, to support the application, and ultimately released an amount of £2,000 deposited with them by the company. The threatened competition in Norwich therefore came to nothing.

Although the National Telephone Company was thus spared the throes of further competition with private companies, it had to adjust its tactics in a limited number of places in order to contend with the active, although in the majority of cases short-lived, opposition which was eventually set up by several municipalities under the Act of 1899. The story of municipal telephone enterprise, embarked upon in 1901, is briefly told in Chapter XIV.

In 1902 the Post Office, acting under the provisions of the Telegraph Act of 1899, and in conformity with the recommendations of the Select Committee appointed by the House of Commons on May 9th, 1898, established telephone service in London, competitive with that of the National Telephone Company, and also began to open up telephone service in numerous villages in the provinces where the telephone had not hitherto penetrated. The activities of the Post Office after this date in their telephone enterprise are dealt with separately in Chapter XV, and therefore need not be discussed further in this chapter.

One of the complaints sometimes made against the company was that it refrained from introducing the telephone into rural and sparsely populated districts. The company was, however, under no obligation to furnish service in localities where insufficient support was forthcoming to make the proposition financially sound. One of the reasons why State ownership of the telephone system was advocated was that the Government would be impelled to supply telephone service at remotely situated centres whether or not they were individually remunerative. Although there are reasonable arguments in support of such a policy, it has also been urged that loss incurred in the supply of telephone service in non-remunerative areas should not in fairness be made good out of the profits secured in other places and that they should be self-supporting. An example of a rural telephone exchange opened by the National Telephone Company at Bakewell, Derbyshire, is illustrated in Fig. 72.

Clause 5 of the Telegraph Act of 1892, which Act embraced the transfer of the National Telephone Company's trunk line system to the State, empowered the Postmaster-General to authorise any licensed company or person to exercise certain of

the powers conferred on the Postmaster-General by the Telegraph Acts of 1863 and 1878. This authority could not be exercised, however, without the consent in London of the County Council, and in any urban district outside London of the Urban Council, and elsewhere of the County Council.

On December 13th, 1897, the Postmaster-General, acting in conformity with the Indenture of March 25th, 1896, issued to the National Telephone Company an "Authority to Exercise Wayleave Powers" within certain specified districts, affecting 29 exchange areas, and on March 23rd, 1899, similar authority was issued in respect of 206 exchange areas. This authority was again augmented on May 7th, 1900, a further 106 exchange areas being affected.

In July 1902 Mr. Dane Sinclair accepted an appointment as general manager of the British Insulated and Helsby Cables Company and therefore resigned his position of engineer-in-chief to the National Telephone Company. In his stead Mr. Frank Gill, M.Inst.C.E., M.I.E.E., the National Telephone Company's superintendent for Ireland, was appointed engineer-in-chief, and he continued to occupy that position until the company's undertaking passed into the hands of the State on January 1st, 1912. During that period it fell to the lot of Mr. Gill to advise the directors of the company in times charged with anxieties and complexities and to pilot the company's staff of engineers through a most difficult and trying period of their experience. Many of the problems encountered during the period of office of Mr. Gill were rendered unique by the fact that the tenure of the company's licence was so definitely limited, and that it was not possible to adopt the same measures which would have been financially sound had there been no such fixed date when the company's operations were to cease. In no other business perhaps is it so necessary to practise foresight and to plan for many years ahead as in the telephone business. The telephone engineer has to deal with widely varying classes of plant and equipment, exemplified by mention of such distinct types as underground ducts and cables, overhead wires, switchboards and their associated power plant. All these vary in their life, in the period for which, under normal circumstances, they should be provided and their treatment during construction and maintenance. The fact that onwards from 1905, when the final agreement was entered into

for purchase of the company's system (as from January 1st, 1912), a period of seven years only remained for the business to be carried on under the existing administration, entirely altered the economic aspect and introduced problems which had to be handled by Mr. Gill and his assistants in a manner special to the circumstances.

Almost from the very outset it appears to have been regarded as inevitable that the telephone system should be owned and worked and the service administered by the State. In the early stages of the history of the telephone the pros and cons of this question were variously discussed, and there were those who were strongly in favour of the Government acquiring and developing the telephone system which had been built up. Evidence of the desirability of Government ownership appeared to have been forthcoming at the early date in its history when the telephone was ruled to be a telegraph within the meaning of the Telegraph Acts. At that time, although the practicability of the telephone as a means of transmission of intelligence had been clearly demonstrated, its possibilities were problematical and consequently the Government decided to permit its development by private enterprise, rather than to undertake itself the financial risk which would have been incurred, reserving to itself the right of purchase at a later date. Having embarked upon this policy, it only became a question as to whether that policy should continue indefinitely or at what date the telephone service should pass into the hands of the State.

Later events demonstrated in a very practical manner the difficulties under which the private telephone companies laboured. They were absolutely dependent upon private land and property owners and public highway authorities for the wayleave essential to the provision of an efficient and economical telephone service and were at their mercy in respect of the terms and conditions of payment they chose to impose. The telephone companies having no statutory powers, public authorities and private property owners were in a position to withhold their consent upon any pretext, and in many instances were only persuaded to grant wayleaves required by telephone companies upon terms considered exorbitant or by pressure of public opinion. Mention has been made of the five futile attempts to promote legislation to vest the companies with the powers they required, but it is

highly probable that the British temperament would not have lightly tolerated such powers being bestowed upon private concerns.

The British Post Office was already in possession of the requisite powers by virtue of the Telegraph Acts, and it was no doubt this fact, coupled with the dissatisfaction frequently expressed, and agitation directed against the telephone service administered by the private companies, which weighed in arriving at the decision ultimately made that the Government should acquire and work the telephone system hitherto conducted by private enterprise.

The Indenture which licensed the National Telephone Company to transact telephone business was dated November 29th, 1884, and covered a period of 31 years from January 1st, 1881. The indenture provided for purchase by the Government of the licensed system by the Postmaster-General giving to the company six calendar months' previous notice in writing to that effect, terminating on December 31st in any of the years 1890, 1897 and 1904.

Possession by the State of the telephone system of the United Kingdom was at last provided for by an agreement, dated February 2nd, 1905, entered into between the Postmaster-General and the National Telephone Co., Ltd., for purchase by the Postmaster-General of the whole of the plant and assets of the company, with certain limitations. The terms of purchase were precisely similar to those of the agreement providing for the acquisition of the company's London plant, referred to in Chapter X. Certain provisions of the London agreement not of general application remained in force. In other respects, the provisions of that agreement were assimilated to those applicable to the rest of the country.

All plant installed by the company subsequent to the date of the agreement was to conform to the terms of "Specification and Rules as to Plant," appended as Schedule III.

The Postmaster-General was empowered to object to purchase plant, land or buildings considered unsuitable for the actual requirements of the telephonic service of the Post Office on December 31st, 1911. Notices of such objection were to be lodged not later than January 1st, 1911. Any difference of opinion between the two parties in relation to the question of suitability of such plant, land and buildings was to be referred

to arbitration. The valuation of plant was to be made on the basis of its fair market value at the time of purchase, due regard being had to the nature, condition, state of repair and suitability for the Postmaster-General's requirements.

The company were bound to surrender to the Postmaster-General all rights of carrying on licensed telephonic business after December 31st, 1911, and to hand over to the Postmaster-General the Licence of 1884 and certain specified agreements.

The Postmaster-General declined to enter into any obligation to take into his service the company's staff, but agreed that it was probable a considerable proportion of the company's officers and servants would be employed on terms to be arranged.

On certain terms the Postmaster-General was to provide underground works and switchboards for the use of the company.

In default of the company maintaining works provided by the Postmaster-General to his satisfaction, such works were to be maintained by the Postmaster-General at the company's expense.

In the event of the telephone service rendered by the company in any area becoming inefficient, the Postmaster-General could call upon the company to take such steps as he might consider necessary to render the service efficient, or to sell to him the plant, land and buildings in such area.

All matters of difference referred to arbitration were to be settled by the Railway and Canal Commission.

The agreements of November 18th, 1901, and February 2nd, 1905, provided, with certain minor exceptions, for purchase by the State of the whole of the company's plant and assets in the United Kingdom. The approaching termination of the company's licence, definitely appointed by these agreements to take effect on December 31st, 1911, militated against the adoption of a broad policy by the company's directors, and there is little doubt that during the period 1900–1912 many forward moves were necessarily withheld owing to the short period they were to continue to provide for the needs of the telephone service. One of the problems difficult of solution in such circumstances was in determining whether the introduction of certain new methods of controlling, administering and working the telephone business was justified. For the benefit of the telephone service administered by the company, it was desirable that nothing should be left undone which would tend towards greater efficiency

of the service and economy in its working. On the other hand, from the point of view of the shareholders it was advisable that capital should not be expended unremuneratively and unless reimbursed by the Government at the purchase date; also that working expenses should not be increased without promise of financial return or resulting economy within the limited period of the company's tenure of licence. The circumstances therefore were generally unfavourable to the furtherance of an extended policy and institution of modern methods, but, in spite of this fact, several new departures were introduced. Some of these undoubtedly were necessary for the carrying on of the business on sound commercial lines and in order to comply with the conditions of the agreements entered into between the company and the Postmaster-General; others perhaps were not so apparently necessary.

In 1902, a department was organised at the company's head office in London for the special study and control of traffic. It was under the direct control of the engineer-in-chief, and was presided over by Mr. W. Napier.

In 1904, an Investigation Department was established at Telephone House, Victoria Embankment, under the control of Mr. B. S. Cohen, whose work in the domain of telephone science is well known.

In 1904 also, a series of courses of study by correspondence, in telephony and allied subjects, was organised for the company's staff and in 1909 the number of students throughout the country was close upon 3000.

In about 1902 a scheme for the inauguration of telephone societies in the larger centres in the United Kingdom was formulated and in 1910 there were as many as fifty telephone societies, not including six operators' societies.

In April 1906 there commenced the publication of *The National Telephone Journal* written by and for the staff of the company. It was discontinued with the completion of the sixth volume in March 1912, but was revived in the form of the *Telegraph and Telephone Journal* under the auspices of the British Post Office.

The complexities of administration and in engineering practice brought about by the advances made in the telephone business, both technical and commercial, were such that in the larger and more progressive towns where development was active, further

changes in organisation became desirable. Consequently, a fuller measure of functional working was introduced and the managers of selected districts were provided with responsible officers with specialised knowledge in charge of a staff expert in the branches of the particular work which they were called upon to do. The diagram in Fig. 73 indicates broadly the district organisation which was brought into force by degrees in the larger provincial cities between 1904 and 1911.

NATIONAL TELEPHONE CO., LTD.

Typical Organisation of Large District, 1904–1911.

District Manager.

District Engineer.	*District Electrician.*	*Traffic Manager.*	*Contract Manager.*	*Chief Clerk.*
Assistant Engineers.	Asst. Dist. Electrician.	Exchange Managers.	Canvassers.	Clerical Force.
Engineering Inspectors.	Exchange Inspectors.	Service Inspector.	Clerical Force.	Storekeeper.
Draughtsmen.	Test Clerks.	Clerks-in-Charge.		
Wayleave Officers.	Chief Inspectors.	Supervisors.		
Clerical Force.	Instrument Inspectors.	Monitors.		
Foremen.	Fitters.	Operators.		
Jointers and Plumbers.	Open Line Faultsmen.			
Wiremen.	Boys.			
Bricklayers and Slater.				
Carpenter.				
Labourers.				
Boys.				

Fig. 73.—Typical District Organisation, the National Telephone Co., Ltd., 1904–1911.

A rearrangement of the headquarters management of the company succeeded the unfortunate death of Mr. W. E. L. Gaine, the company's general manager, which took place in July 1907. The position thus made vacant was not filled. Mr. George Franklin had become president of the board of directors in succession to Sir Henry Fowler, who resigned that position in 1906, and himself undertook the duties of managing director, Mr. Stanley J. Goddard, who had previously acted as assistant general manager, being appointed general superintendent. Mr. Gaine's successor in the capacity of solicitor to the company was Mr. William Edward Hart, Deputy Town Clerk of Sheffield.

In March 1907 a case was heard by Mr. Justice Swinfen Eady respecting the ability of the Postmaster-General to demand and the obligation of the National Telephone Company to pay a royalty on certain classes of private telephone line. Section 5 of the Telegraph Act of 1869 excludes from the statutory monopoly of the Post Office " telegrams in respect of the transmission of

FIG. 72.—Example of a Rural Telephone Exchange, Bakewell, Derbyshire.
(From a photograph by Mr. E. J. Johnson.)

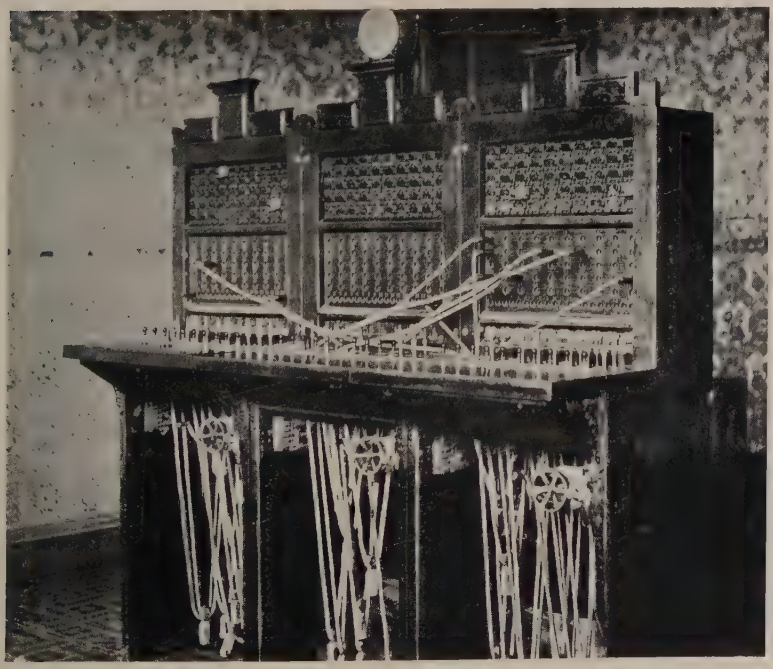

FIG. 74.—Switchboard, Rotherham, 1896.
(From a photograph by Mr. E. J. Johnson.)

[*To face page 222.*

which no charge is made, transmitted by a telegraph maintained or used solely for private use and relating to the business or private affairs of the owner thereof," and "telegrams transmitted by a telegraph maintained for the private use of a corporation, company or person, and in respect of which, or of the collection, receipt and transmission or delivery of which no money or valuable consideration shall be or promised to be made or given."

The case dealt with two schedules, the first of which included private lines from a theatre to a fire station, a doctor to a chemist, a theatrical agent to a theatre, a company to its solicitors, and the like. The company contended that for all practical purposes these should be taken as from A to A, that is to say, they existed for the purpose of the party who paid rental for them and were utilised entirely for his business.

Schedule 2 included fire alarm signals in which no telephone whatever was used, and the company contended that fire alarms and similar signals related to the business or private affairs of the owners thereof, that no charge was made for the transmission of signals and that the apparatus was maintained solely for private use.

Mr. Justice Swinfen Eady decided against the company in both cases, declaring that the telegraphs in Schedule 2, not being fitted with telephones, were not within the company's licence. The company appealed against this decision and the Court of Appeal declared in the company's favour on the construction of the Act. The matter was therefore taken to the House of Lords by the Post Office and again the decision was reversed.

The result was that the Postmaster-General won the day and the company were debarred from conducting the business of fitting fire alarms and similar signalling systems when telephones were not used and were under obligation to pay royalty in respect of A to B lines. The decision in this case appeared to place the Post Office in the position of being able legally to demand, if they desired to exercise their full rights, royalty on all electric signalling systems over which signals are not exclusively transmitted by and for the party for whose use they exist, and it would seem that in a legal sense the ordinary house door bell with other similar signals, not being an A to A line, is not immune from the Government's monopoly.

In view of the termination of the company's activities at December 31st, 1911, and therefore of the fact that in the ordinary course of events the company would not make any provision for the development of the telephone system beyond that date, it was desirable that some arrangement should be made whereby the needs of the service for a reasonable period beyond 1911 would be provided for. Consequently as one of the means towards this end, an agreement dated August 24th, 1909, was entered into between the Postmaster-General and the National Telephone Company under the title " Heads of Arrangement between His Majesty's Postmaster-General and the National Telephone Company, Limited, for facilitating the execution of certain classes of construction work in connection with the Company's system to provide for periods extending beyond 1911." This agreement set forth the conditions under which schemes which might be prepared by the National Telephone Company should include provision for a period extending beyond the date of expiration of their licence.

On September 14th, 1910, a further agreement was completed between the Postmaster-General and the company headed: " Supplemental Heads of Arrangement for facilitating the Establishment of New Exchanges in Outlying Districts of the Company's Areas." This agreement was entered into in order to permit of the development by the company of areas in which exchanges had not previously been established.

The terms under which the telephone system owned by the National Telephone Company was to be purchased by the State were those known as " tramway terms," *i.e.* the price to be paid was the value *in situ* of the plant without any payment being made for business goodwill except in so far as the company's private wire business and certain competitive systems were concerned. It was therefore necessary to know exactly what were the quantities of the numerous items of plant which were to be purchased, and in such a large undertaking the only solution likely to prove satisfactory to both parties, although admittedly costly, was for a special inventory of the plant to be taken, and this course was decided upon.

The taking of the inventory was the subject of an official agreement between the Postmaster-General and the National Telephone Company, dated October 5th, 1910.

Preparations for the task of compiling the inventory were commenced in September 1910. The whole of the plant in the United Kingdom had to be visited, the various quantities ascertained, checked and agreed upon, and in addition endeavour was made to ascertain the age of the several items of the company's plant to be specified in the inventory, a prodigious task for the staff of the company and also of the Post Office. The enumeration of the items of plant was done by officers of the company specially deputed for the work and similarly appointed parties of Post Office engineers accompanied them and checked and agreed the quantities. It was desirable that the work should be completed before the end of the year 1911. A staff of over four hundred of the company's engineers was organised for the purpose under the immediate superintendence of Mr. A. Watts, and two hundred officers of the Post Office were also associated with the undertaking, the field work being completed in approximately twelve months.

Purchase by the Government of the National Telephone Company's huge undertaking was a matter of considerable importance both to shareholders of the company and the British public. From the point of view of the shareholders, it was desirable that the directors of the company should take all reasonable steps to secure that the highest possible price was obtained for the undertaking which they were bound by agreement to sell, and it was equally essential that the custodians of the public purse should pay no more for what they were to purchase than was fair and equitable. Both parties were therefore justified in the steps which they took towards these respective ends.

It was barely to be expected that the purchase of an undertaking representing a capital expenditure of many million pounds would be completed without some difference of opinion between the contracting parties, and although differences arising in connection with the inventory were settled without very much difficulty by virtue of their concrete nature, the rulings of the appointed arbiters had ultimately to be sought to settle points of difference associated with the purchase price.

According to the terms of the two agreements of November 18th, 1901, and February 2nd, 1905, which provided for purchase of the National Telephone Company's plant on tramway terms,

the Postmaster-General was empowered to object to purchase plant situated in non-competitive areas not constructed in accordance with the agreed specification, and in competitive areas to plant which he considered to be unsuitable to his requirements whether or not constructed in accordance with the said specification. Notices of objection had to be lodged by January 1st, 1911. Notices of objection to the number of seventeen were accordingly served upon the company during the year 1910. Not unnaturally, the company were disinclined to submit to these objections without making strenuous endeavours to secure their reversal, and consequently, in accordance with the terms of the agreements mentioned, made application on February 9th, 1911, to the Court of the Railway and Canal Commission who were the appointed arbitrators for an award that the notices of objection referred to were null and inoperative.

The case commenced on May 9th, 1911, and was heard before Mr. Justice A. T. Lawrence, the Hon. A. E. Gathorne-Hardy and Sir James Woodhouse. An interesting feature of the case was a series of models prepared and exhibited by the company. They were for the purpose of illustrating to the court any feature of telephone engineering which might require demonstration. Some particulars and illustrations of the models are given in the *National Telephone Journal* for June 1911.

The two points of chief importance raised were, first, whether the notices served by the Postmaster-General were in whole or in part invalid and the second involved the determination of what plant, land and buildings the Postmaster-General was entitled to exclude from the purchase. The case largely turned on the interpretation to be placed upon the term "unsuitable." The case concluded on May 18th, 1911, and judgment was pronounced on May 29th. Mr. Justice A. T. Lawrence and Mr. Gathorne-Hardy held that the first part of the notice, referring to London, was good and the second bad, and that the notice relating to the non-competitive areas was bad, while Sir James Woodhouse differed from his colleagues and considered that the Postmaster-General was entitled to judgment.

Notice of appeal was given and the appeal was heard on June 14th, 1911, by the Master of the Rolls, Lord Justice Farwell and Lord Justice Kennedy. On June 28th judgment was given in accordance with the findings of Sir James Woodhouse, and

the National Telephone Company was ordered to defray the costs of the appeal.

Further progress was made towards the fixing of the price which was to be paid by the Postmaster-General to the National Telephone Company on July 3rd, 1911, and following days, when the Court of the Railway and Canal Commissioners again met and further inquiry into the case was conducted. On July 11th, before the case was brought to a conclusion, the Attorney-General announced that a form of declaration had been agreed upon, which in the main consisted of an agreement between the contending parties that the whole of the Notices of Objection should stand subject to certain modification; the notices relating to competitive areas would be withdrawn, excepting the case of Abergavenny, and in these competitive areas the Post Office would purchase all the plant subject to certain stated conditions.

At midnight on December 31st, 1911, the plant, property and assets of the company passed into the hands of the Postmaster-General upon terms providing (*inter alia*) for payment of interest on the amount of purchase money from time to time unpaid at the rate of three per cent. per annum until June 30th, 1912, and thereafter at the rate of five per cent. per annum.

On February 9th, 1912, the company made formal application to the court of the Railway and Canal Commission to settle and determine the amount of the purchase money to be paid to it by the Postmaster-General for the value of its plant, property and assets, and the company's claim was duly filed with the court on April 2nd, 1912.

On Monday, June 10th, 1912, the arbitration proceedings proper commenced. In view of the inventory which had been completed whereby quantities had been agreed, there was no dispute between the contending parties as to quantities, but the Post Office disagreed with the value which had been assigned to the plant by the National Telephone Company's engineers. The company claimed £20,924,700 as the amount of purchase money, whereas the Post Office valuation amounted only to £9,381,048.

It was agreed that in the first instance the evidence should be directed solely to the value of the company's plant, which formed the chief part of the items composing the claim.

During the progress of the case and in response to intimations

from the court, it became necessary for endeavour to be made to arrive at an agreement respecting :

(*a*) The basic costs of the labour, material and freight in respect of plant without regard to other necessary charges more or less founded upon them. These costs were ultimately agreed at £10,239,345.

(*b*) The value to be allowed for land and buildings and all other items (except plant) included in the claim. This was agreed at £2,055,468.

These agreements arrived at between the contending parties had the effect of considerably shortening the proceedings. There was then left to the Railway and Canal Commission to determine what were the proper additional charges to be allowed the company incident to the construction of its plant and what sum should be deducted for depreciation.

The award was given on January 13th, 1913, the total amount being £12,515,264. Sir James Woodhouse disagreed with the majority of the court in respect of an amount of £247,189, which represented the cost of raising capital, and which he considered should be disallowed. Costs were ordered to be paid with the Post Office.

On February 3rd, 1913, by reason of the difference of opinion of Sir James Woodhouse, the Postmaster-General gave notice of his intention to appeal against so much of the judgment of the Railway and Canal Commissioners as awarded to the company the sum of £247,189 for the cost of raising capital and £150,000 for the cost of obtaining subscribers' agreements; the company raised a counter appeal in respect of various questions which gave promise of creating further lengthy proceedings. The Court of Appeal, composed of the Master of the Rolls, Sir H. H. Cozens-Hardy, Lord Justice Buckley and Lord Justice Kennedy, on a point of jurisdiction raised by Mr. Danckwerts on behalf of the company ruled that a right of appeal existed.

On June 23rd, when the case again came before the Court of Appeal, it was announced that the parties had come to an arrangement and that the appeal and counter-appeal should therefore be dismissed. The court was apparently gratified at the settlement which had been consummated and made the necessary order on July 1st.

The total sum as now agreed to be paid to the company

was £12,470,264 as compared with £20,924,700, the original claim.

The plant purchased comprised the following :—

Number of telephone exchanges	1,565
Number of telephone stations	561,738
Number of miles of wire	1,500,000

In the *National Telephone Journal* for November and December 1911 and January 1912 Mr. Albert Anns, secretary to the National Telephone Company, contributed an article in three parts, entitled " The History of The National Telephone Co., The trials, tribulations and triumphs of thirty-three years." Information of great historical interest relative to the telephone service in this country is given by Mr. Anns, and the author has drawn freely from it in writing these records. Mr. Anns concludes his article with the following paragraph :—

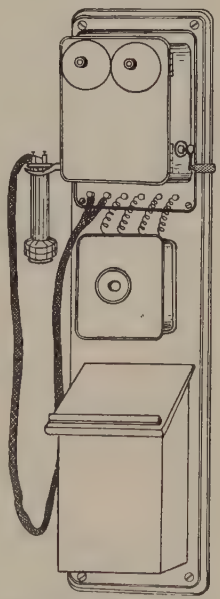

Fig. 75.—Type of Wall Telephone employed for many years by the National Telephone Company.

" The trials, tribulations and triumphs of the past 33 years will soon be only a memory. Through storm and sunshine, good fortune and bad the National Telephone Company has moved to its appointed end conscious that at all times it has given of its best in earnest endeavour to do its duty, often under circumstances of extreme trouble and difficulty. That it has not realised its highest ideals is not the fault of the company, for the forces arrayed against it have on many occasions proved to be too powerful. It has been attacked and threatened in quarters where it had a right to expect help and encouragement, but it confidently anticipates that the verdict of posterity will be that the National Telephone Company deserved well of the nation."

CHAPTER X

THE NATIONAL TELEPHONE COMPANY, LIMITED, IN LONDON 1884–1912

THE United Telephone Company relinquished and the National Telephone Company assumed responsibility for the administration of the telephone service of the Metropolis and its environs on the amalgamation on May 1st, 1889, of the three principal telephone companies, namely, the United, the National and the Lancashire and Cheshire companies, and the association with the London telephone service of the name of the United Telephone Company thus came to an end.

As at January 1889, the United Telephone Company's system in London comprised 21 exchanges serving 5520 subscribers' exchange lines, and 1438 private wire renters with a wire mileage of approximately 9000. There were 28 call-rooms available to the public and others were in course of being opened. Subscribers were allowed the use of these call-rooms free, a charge of sixpence being made to non-subscribers.

Dissatisfaction frequently had been expressed with the United Company's management of the Metropolitan system, and charges made that a policy of stagnation and utter disregard of modern discoveries and improvements in telephony had been followed by the London management. Whether or not such allegations were well founded, better things certainly were expected of the amalgamation in the prosecution of a more progressive policy in respect of the telephone service of the Metropolis.

Mr. James Brand, chairman of the United Company, who had been prominently identified with the telephone service in London ever since its inception, declared his decision not to accept a seat on the board of the newly-constituted company, and Mr. Frederick R. Leyland was elected president. Mr. Joseph B. Morgan, hitherto managing director of the United Company, was not appointed to any executive post

Mr. Dane Sinclair, engineer for the Glasgow district of the National Telephone Company, was commissioned to examine and report upon the London telephone system and, after he had done so, became the first manager for London under the new *régime*. Mr. Thomas Fletcher and Mr. Charles J. Phillips retained, respectively, the positions of chief engineer and chief electrician.

Reconstruction of the London line plant was quickly put in hand; channel iron cross arms carrying upright insulators were substituted extensively for the shackle bell insulators affixed to the vertical members of roof structures, and the previously existing galvanised iron wires gradually gave place to bronze wires of 40 lb. per mile.

The problems which presented themselves to the engineers responsible for the London telephone service soon after the United Company's business passed into the hands of the National Telephone Company were not insignificant. Amongst them was the determination of the type of switching equipment which should be employed generally. At the period in question, the design and constructional details of switchboards were in a state of flux, due to the rapid advances which were being made, and it was therefore not an easy matter to decide upon a policy which might be rigidly followed. One of the questions which occupied a good deal of attention, and upon which opinion was at the time somewhat divided, was the vexed one of the relative merits of the upright *versus* the flat multiple switchboard.

Experience gained by those concerned in the operation and maintenance of the Hawes multiple boards at Chancery Lane and Oxford Court from 1884 to 1889 and the upright multiple boards which succeeded them had demonstrated that from an operating and a maintenance point of view the advantages lay decidedly with the upright board.

The disadvantages urged against the flat type of board may be epitomised as follows :—

(1) Difficulties of construction owing to the necessarily cramped arrangement of multiple cables and the separation of the various units of plant in table and canopy.

(2) Difficulties of maintenance due to the necessity for withdrawing strips of jacks which had to be attended to from the front and the inaccessibility generally of cabling and other switchboard accessories.

(3) Difficulties of operating due to (*a*) the jacks being placed at a greater average distance from the operator, necessitating frequent assistance by a second operator in handling calls; (*b*) the reduced facility for selecting and inserting the plug into jacks placed in a horizontal rather than a vertical plane; (*c*) the reversal of the numbering of the jacks to operators situated on one side of the multiple; (*d*) the obstruction to operators' movements caused by the cords over the multiple, and (*e*) disturbance due to execution of repairs during working hours.

The only real advantage which rightly could be claimed by advocates of the flat board, as compared with the upright, was the lower first cost. This economy was entirely due to the reduction in expensive multiple equipment, the patent for which was still in force, and was to some extent counterbalanced by the higher costs introduced by the greater difficulties of construction arising from the more complex and cramped arrangement of the plant.

A good deal of time was spent in considering the question as to whether flat or upright boards should be employed for London exchanges, and although the preponderance of expert opinion was against the use of flat boards, owing to the disadvantages they suffered and the evident superiority of the upright board, the question of prime cost eventually gained the day, and a number of flat boards were eventually provided.

The first was Holborn, brought into use in 1894. To this exchange were diverted the subscribers previously served by Chancery Lane. Bank (Queen Victoria Street) followed in December 1894, and Hop and Gerrard quickly afterwards.

Some particulars of the design and arrangement of the flat switchboards fitted in London, all of the self-restoring-indicator branching multiple type, appear in Chapter XI. A photograph showing the Gerrard flat switchboard under construction in 1895, kindly supplied by Mr. Alfred Perkins, is reproduced in Fig. 76.

As soon as the Edison patent expired on July 30th, 1891, competition was again threatened in London. The prime mover was the late Duke of Marlborough, who hoped to compete successfully with the National Telephone Company in London, and elsewhere, by establishing a metallic circuit system with service at an annual tariff of £12 12*s.* 0*d.* The Postmaster-General, however, declined to issue the requisite licence empowering the com-

pany to commence operations; but, nothing daunted, the Duke of Marlborough conceived the idea of acquiring the title of the New Telephone Company, together with the licence possessed by that company. The circumstances associated with the formation of the New Telephone Company and the suspension of its operations have been related in Chapter VI. The proceedings in connection with the liquidation of the New Company had already commenced, but they were arrested, the New Telephone Company was revived, and its reconstruction put in hand.

With the Duke as chairman, the company then made preparations for opening up telephone service in London. Plant was placed on order and premises were taken.

In August 1891 Mr. A. R. Bennett, general manager and chief engineer to the Mutual Telephone Company of Manchester, read a paper before a meeting of the British Asociation at Cardiff, entitled, "On the Telephoning of Great Cities." The system outlined was one Mr. Bennett had devised and which, in a letter addressed to the *Times*, the Duke of Marlborough stated was intended to be adopted by the New Company for their London system.

In his paper Mr. Bennett set out to show how the peculiar conditions pertaining to London might best be provided for, and he assumed that legislative assistance to the extent of placing the undertakers of telephone exchange systems on an equal footing with the purveyors of other public utilities, such as gas, water and electric light undertakings, which were indispensable to the carrying out of a scheme designed, not only to meet the requirements of the moment, but those for a reasonable number of years to come, would be forthcoming.

Mr. Bennett defined the conditions indispensable to the establishment of an effective and popular telephone exchange service in a large town as follows:—

"*First.*—Speech must be loud and distinct and privacy of communication complete; and a subscriber's line and apparatus must be adapted equally well to speaking to another across the street or to one 500 miles away. There must furthermore be absence of all disturbing sounds.

"*Secondly.*—The arrangements for connecting the subscribers together, subsequently disconnecting them and, if required immediately, reconnecting them to others, must be so complete

that eight or ten seconds should be the maximum time occupied within the compass of the largest town.

"*Thirdly*.—The rates must be within the reach of even small householders and shopkeepers and should not exceed £8 per annum.

"*Fourthly*.—The general design must permit of the addition of new subscribers in every direction, and to any extent, without interfering with the work already done."

It was claimed in the paper that all these conditions could be complied with by the adoption of the measures below indicated :—

"1. The universal use of metallic circuits, and the absence from the line of intermediate electro-magnets and other signalling devices, which tend to damp and deform the electrical vibrations which constitute telephonic speech.

"2. The provision of means by which certain and instantaneous communication can be established between subscriber and operator, and between one operator and another.

"3. The division of the town to be telephoned into districts or sections not exceeding a square mile in area, each of which is worked from a switch-room placed at or near its centre."

Broadly considered, the suggested system resolved itself into the exclusive use of metallic circuits for conversation between subscribers, and the employment of a modified form of the Mann Call-wire system for signalling. The objection to the Mann Call-wire system in that it involved the provision into each subscriber's office of a branch from a common service wire, over which all communications between operators and subscribers were conducted, was to be overcome by the adoption of an arrangement which was termed the "static call wire." This device depended upon the provision of a call wire, to which the operator's receiver was normally connected, parallel with the group of subscribers' circuits associated with it and insulated at its farthermost extremity. By means of a call key, the subscriber was to be enabled to earth the two wires of his metallic loop in parallel, through his receiver, and the phenomenon of electro-static induction between the circuit thus formed and the call wire, was to be relied upon to furnish means of communication between subscriber and operator.

Connections through more than one switch-room were to be asked for by each operator concerned successively depressing a

lever in order to place her in communication with a service wire on which the operator at the next exchange was listening.

Mr. Bennett's ideas were covered by patent. British Patent Specification No. 7283, of April 28th, 1891, describes a means for providing additional telegraph or telephone transmission by employing lengths of insulated conductors parallel to the existing circuits, and utilising electro-magnets or condensers connected to earth at the outer ends. British Patent Specification No. 11294, of July 3rd, 1891, describes an arrangement of apparatus for signalling to an exchange without connection to a switch-board, by means of an extra conductor inductively disposed to the line wires of the subscribers.

In the letter to the *Times* previously referred to, the Duke of Marlborough stated that a new company, which was in possession of a licence from the Postmaster-General, was about to promote a Bill before Parliament during the following session, with the object of establishing a complete twin wire telephone service for the whole of London, on the basis of a rental of £10 per annum, and with a system on the plan worked out by Mr. Bennett.

The Duke expressed the opinion that a satisfactory service in London could be established at a remunerative profit for a subscription of £10 per annum, and that it was to be feared the National Telephone Company would never be able to reduce their rates to that level, as all the money they paid for patents should be written off that year, their last important patents having expired.

Early in 1892, the New Telephone Company advertised its intention of establishing a twin wire efficient telephone service in London. The annual rental to be charged each of the first 5000 subscribers was £12 12*s.* 0*d.* and for others £14; no charge was to be made until 3000 subscribers' lines had actually been connected and were working. A canvass for subscribers was undertaken, and trunk communication between London, Manchester, Liverpool, Glasgow and other important towns in Great Britain was offered.

The Duke of Marlborough induced the City of London Electric Lighting Company, of which he was a director, in laying down their system of mains for electric light distribution, to lay in their trenches while open for the installation of electric light conduits extra or spare pipes sufficient in number to meet the anticipated

future demand for telephone service. Negotiations were also entered into with other electric light companies in the City with the same object in view. It was reported that 147 miles of 2½ inch pipe were eventually laid and that £69,000 was spent in this provision.

On July 27th, 1892, the business opened in Manchester by the Mutual Telephone Company, referred to in Chapter IX, was sold by the Pioneer Telephone Co., Ltd. (who acquired it on February 26th, 1892), to the New Telephone Co., at a purchase price of £90,000; Mr. A. R. Bennett, the Mutual Company's general manager and chief engineer, was retained in that capacity by the New Company.

The determined attitude of the New Telephone Co., Ltd., in pursuing their avowed intention of establishing a competitive telephone service in London, coupled with the dissatisfaction evinced at that time by the subscribers to the National Company's London telephone system, was the source of some considerable concern to the directors and executive officers of the National Telephone Company. The company's London system had by that time grown to such a size that the particular problems associated with the telephoning of such a large and congested area had assumed a definite character, and become more or less crystallised, and were well appreciated by those who had practical experience of them. The determination of the measures best calculated to dispose satisfactorily of these problems was, however, another question. The familiar complaints of failure to clear, and the incessant inquiry, "Have you finished?" the result, no doubt, of the peculiar conditions of the Metropolitan junction service, were common, and the question arose as to the means to be adopted and the steps to be taken to remove the cause for complaint which apparently existed, and to provide for London subscribers the best possible telephone service.

To telephone engineers of modern times acquainted with the telephone requirements of large and congested cities, it may appear surprising that the call-wire system should ever have been seriously suggested for London. Apart, however, from the serious objections which attached to the call wire itself, the system embodied certain particularly attractive features at the time under review; principally these were the absence of signalling apparatus and its attendant complications in the talking

circuit, and secrecy, or the impossibility of operators connecting their receivers in circuit with the subscribers' lines. Considered in the light of present day telephone switching practice these features have, however, become insignificant.

Following then upon the New Telephone Company's proposals, the National Telephone Company's experts deliberated upon the desirability of introducing the call wire into the London telephone system, but after careful consideration the question was decided against the call wire for subscribers' use, and therefore the magneto system continued to be employed and extended.

The sudden death of the Duke of Marlborough in November 1892 deprived the New Telephone Company of its enthusiastic and enterprising head, and its activities afterwards languished. To those who were associated with the Duke in the enterprise, in which he had been the moving spirit, it became apparent that the policy of the Government in assuming possession of the trunk wires forming the inter-town communication of the country would greatly complicate the position of the licensed companies, and make unity of administration and interest essential to efficiency and success; the necessity for still closer union with the National Telephone Company therefore became recognised, and matters ended in the National Telephone Company acquiring, partly by purchase and partly by the exchange of New Company's shares for National shares, nearly the entire interest in the New Company.

The astute directors of the National Telephone Company thus secured a proponderating influence in the affairs of the New Company which, at their volition, went into voluntary liquidation. It was not until August 1898, however, that the company was finally dissolved and the business, passing entirely into the hands of the National Company, the threatened competition in the Metropolis, as also the competition in Manchester, was brought to an end for the time being.

In the report of the directors of the National Telephone Company for the year ending April 30th, 1893, reference is made to the action taken relative to the threatened competition of the New Telephone Company in the following terms:—

"The promoters of that enterprise soon began to appreciate the serious difficulties which lay before them and, as the result of discussion accepted the conclusion that if the shareholders were

to be secured a reasonable return upon their capital it would be better in the public interest to work in harmony with the National Telephone Company, adopting as far as practicable the better features of the two systems. This resulted in an agreement under which the National Telephone Company subscribed one-third of the capital of the New Company, and were represented on the board of that company."

In Chapter III the outcry which took place, principally in London, in the time of the United Telephone Company, against the unrestricted employment of overhead wires, and the attempts which were made to place them under authoritative control is dealt with.

The National Telephone Company were not destined to have things all their own way in regard to overhead plant, however, and on July 3rd, 1891, an Act of Parliament, known as "The London Overhead Wires Act, 1891," was passed. It was an Act to provide for the control and regulation of overhead wires in the administrative County of London. The preamble, which explains its chief objects, read as follows:—

"Whereas the number of wires and cables placed overhead within the administrative County of London has increased and is increasing, and such wires and cables are subject to no efficient system of control or regulation, and it is expedient that provision should be made as in this Act contained for the control and regulation of all such wires under bye-laws made as hereinafter provided and for the removal or alteration of such wires and cables in certain cases."

All companies or persons having placed, or claiming any power to place, wires overhead in the county were embraced within the Act.

The Chief provisions of the Act were, that new overhead wires were not to be erected except in accordance with the bye-laws, that rights over private property were not to be acquired except by agreement with the owner of the property concerned, and that the Council were empowered to make and vary bye-laws to be approved by the Board of Trade with respect to certain prescribed matters. Removal of existing wires might be demanded in cases where danger to the public might be apprehended. Wires were not to be inconsistent with regulations of the Board of Trade. The provisions of the Act were not applic-

able to undertakers acting under special Act, Provisional Order, or licence under the Electric Lighting Acts, 1882 and 1888, neither to wires erected exclusively on private property, for use of the owner. The Postmaster-General was totally exempt from the provisions of the Act.

A copy of the bye-laws eventually formulated by the London County Council is furnished in Appendix D.

The London Overhead Wires Act, 1891, placed the National Telephone Company, as well as other companies possessing aërial wires in London, under an obligation to conform to the bye-laws referred to. Briefly stated, these bye-laws provided for delivery to the Council and the local authority of full particulars of the material, and gauge of the existing wires of the company, the nature and position of the several supports and the length of span between supports; also for information to be supplied, showing the line of route of all existing wires. Restrictions in regard to new wires, as to length of span, height of crossing above street, ground or roof, as the case might be, were imposed; a factor of safety for suspended conductors of at least four at a temperature of 22° F., and ten for all structures was stipulated. Every support was to be marked in an approved manner and no cable was to exceed one pound per lineal foot in weight. An interesting development arose out of the last-mentioned stipulation.

As mentioned elsewhere in this volume, the National Telephone Company were unable to come to terms with the London County Council regarding the installation of underground cable plant within the jurisdiction of the Council, and the company was therefore compelled to have recourse to overhead wires. The telephone density in London, particularly within the confines of the City, was such that provision of the necessary wires was a task of no mean order; although arrangements were ultimately made whereby the Post Office should, under certain circumstances, provide, and the company should rent from them certain underground plant, the facilities were not such as would have been afforded had the company been in a position to lay its own plant; the result was that the use of underground conductors by the company was severely limited.

A good deal of attention was therefore bestowed by the company's engineers upon the design of overhead plant to meet the

peculiar conditions pertaining to London. The exclusive use of open wires in such numbers as were required was entirely out of the question. Lead-covered cable was also impossible by virtue of its weight and the London County Council's bye-laws. The maximum number of wires which could conveniently be accommodated in aerial cable of the designs available with rubber or similar insulation was insufficient for the requirements of a locality with such a high telephone density, and the cost of such cables was considerable. Attention was therefore directed towards the production of a new type of aërial cable which would accommodate the largest possible number of conductors compatible with transmission and mechanical requirements and also satisfy the stipulations as to weight, at reasonable cost. Eventually the "rubber covered dry core cable" was evolved, a type of cable which played an important part in the telephoning of London and therefore deserves mention. This type of cable was first introduced in 1898; it consisted essentially of paper insulated wires enclosed in a vulcanised india-rubber tube, suitably braided externally. Particulars of the classes of cable of this type eventually regarded as standard are given in Table No. 5. It will be observed that the 50 pr.-20 lb., 100 pr.-10 lb., and 150 pr.-6½ lb. cables were each less in weight than 3 lb. per yard, and cables up to this size therefore satisfied the conditions imposed regarding weight.

These cables were satisfactory immediately after erection, but eventually proved troublesome from a cause unusual with cables of the paper core type, and a source of no little anxiety to the responsible engineers. Insulation was found to be unreliable, and subject to fluctuations of a serious character with changes of temperature, falling to seriously low proportions in the hotter summer weather. Desiccation by ordinary means was not as effective as with lead-covered cables, and it was no uncommon occurrence for all available desiccators to be running continuously, night and day, during the hottest weeks of summer. Showers of rain were as anxiously looked for by London telephone engineers as by country farmers after prolonged drought, but for a different reason, and by their cooling effect the situation was frequently saved where common battery exchanges were concerned.

A good deal of time and money was unavailingly expended in

FIG. 76.—Flat Switchboard with Self-restoring Indicators and Branching Multiple under construction at the National Telephone Company's Gerrard Exchange, London, 1895.

(From a photograph by Mr. Alfred Perkins.)

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FIG. 77.—Derrick and Test Hut, 31 Throgmorton Street, London, E.C.

(From a photograph by the author.)

FIG. 78.—Form of Junction Box associated with the City of London Overhead System.

(From a photograph.)

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investigation and experiment, in the endeavour to eradicate the trouble which seemed inseparable from the use of india-rubber as cable sheath. The cause of the loss of insulation was regarded as being due to some of the residual or inherent moisture, necessarily present in the rubber to maintain satisfactorily its stability, being expelled by the increase of temperature due to the rays of the sun, and absorbed by the paper insulation of the wires contained within the rubber envelope.

From the inception of telephony, the telephoning of London presented peculiar difficulties of its own not met with in any other city in the world. Construction of the overhead system commenced by the two parent companies and continued by the United Company was of necessity carried on by the National Telephone Company, and under its *régime* a huge network of overhead wires and cables was gradually built up.

No one without practical experience can possibly appreciate the immensity of the work involved in giving service to large numbers of subscribers, situated within the confines of the City of London, by overhead means. The mass of overhead wires, cables and structures was accepted by the London public as it accepts the tubes, the 'buses, and other services, with little thought to the reason for its existence, or as to why London could not be saved the indignity which attached to such a system, when many of the more favoured provincial cities were served largely by underground cables. The sewers, subways, tubes and other railways and artesian wells which comprise underground London have all received literary mention on various occasions, but the London overhead world has been accorded scant attention, in spite of its novelty. A visit by the uninitiated to the roofs of the City of London when the telephone service was administered by the National Telephone Company would, no doubt, have been a matter of considerable interest. On many of the roofs of these high buildings one might walk without impediment for considerable distances, crossing from one building to another either direct, or by means of gangways specially provided for the purpose. A peculiar quiet reigned in spite of the noise of traffic in the busy streets below. One seemed translated from the world of the London streets to quite a different and remote world, seemingly without any relation to the London of common conception. In all directions amidst chimney stacks, ventilators,

water tanks, and other peculiar appurtenances, radiated innumerable wires and cables of various sizes, supported on huge derricks, roof poles and standards, with their numerous stays, the whole inanimate, without apparent purpose, yet constituting the principal medium by which the citizens of London conducted their communications. This realm of wire, both insulated and bare, was as well known, or even better than the streets below, to the men who lived their daily lives within it, attending to its peculiar needs, extending it or adding to or subtracting from it as occasion demanded.

This distributing system, although unsatisfactory from many points of view—no telephone engineer would have objected to its wholesale demolition following its replacement by a modern underground system—possessed certain advantages, however. Its arrangement was such that a high degree of flexibility was attained, and so long as serious disturbance due to wayleave or other trouble did not arise, alterations could be made with commendable rapidity. With an underground system in a city like London, street traffic considerations and the congestion of mains and pipes of all classes which exists beneath the surface exercise an important influence in the construction, extension and maintenance of the plant, and introduce no little difficulty and obstruction in the way of the responsible engineers.

Overhead, different difficulties existed in the form of gaining access to required localities, negotiating obstructions in the form of chimneys and other protuberances, disturbance of plant due to building operations, fire and storm, securing necessary wayleave, and last, but not least, the careful inspection and maintenance essential to plant subjected as it was to the decay and corrosion brought about by a somewhat moist and acid atmosphere.

In the City of London flexibility in distribution was, and still is, an important and valuable factor in the provision and maintenance of telephone services, largely because of the high proportion of miscellaneous services which have to be provided for. By the term miscellaneous services is meant those telephone circuits which need not of necessity pass to or *via* the telephone exchange, in other words, those circuits which are not subscribers' exchange lines or junctions. In the neighbourhood of the Stock Exchange, Shorter's Court and Warnford Court in Throgmorton Street, which are within almost a stone's throw of the London

FIG. 79.—Derrick and Aërial Cable Runway, Bank Exchange, London, 1909.

(*From a photograph by the author.*)

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FIG. 80.—Octagonal Iron Structure for support of Overhead Wires and Cables, Avenue Exchange, Lime Street, London.

(From a photograph by the author.)

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Wall Exchange, the number of miscellaneous services in the form of private lines is actually very greatly in excess of the number of exchange services. The proportion of miscellaneous to exchange services in a normal exchange area is usually of the comparatively low order of from five to fifteen per cent., and such a large proportion of non-exchange services in the area in question has a very disturbing effect on the line plant lay-out and design, and introduces problems of distribution absent in a normal area. Flexibility of the distributing system therefore becomes a factor highly desirable of attainment. With the National Telephone Company's overhead system in London flexibility was secured by the provision of numerous subsidiary distributing centres, usually in the form of junction boxes connected by aërial cables.

The photograph reproduced in Fig. 77 is of a large derrick situated upon the roof of 31 Throgmorton Street, which formed the largest of these overhead distributing centres. Within the hutment enclosed between the four iron uprights of the structure were terminated at one time 62 aërial cables, containing 3258 circuits, and provision was made for cross connecting them in any manner which might be desired. The activity caused by new connections, removals, alterations and testing necessitated almost constant attendance at this point, in fact it constituted a test-room in miniature.

A form of junction box, for the purpose of terminating aërial cables, contributed largely to the flexibility of the system and is illustrated in Fig. 78. As many as 500 of these junction boxes were at one time in use on the roofs of the City of London alone.

Another photograph, reproduced in Fig. 79, is of the derrick which existed over the historic exchange known as "Bank," in Queen Victoria Street. The photograph was taken in 1909. St. Paul's Cathedral may perhaps be discerned in the distance through the haze. The peculiar cable runway in the foreground conveyed aërial cables between the Bank Exchange and the one-time trunk exchange situated at Oxford Court, Cannon Street.

Fig. 80 is from a photograph of the huge structure for the support of overhead wires and cables which surmounted the National Telephone Company's "Avenue" Exchange in Lime Street, London.

An operation which frequently excited a good deal of public

interest in the streets of London was one pertaining to the maintenance of the numerous aërial cables, namely, that of the renewal of the No. 10 S.W.G. galvanised steel wires from which the cables were suspended by means of raw hide slings; the number of such wires used for one cable was proportioned according to the weight of the cable to be supported and to the length of the span. These steel wires had an effective life, in London, of something of the order of seven years, and it was therefore no infrequent occurrence for the operation of renewal to be witnessed. That part of the work which aroused the wonderment and sometimes the concern of the public is depicted in Fig. 81, and consisted of the transfer of a cable from the old to a new set of suspending wires erected for the purpose, by a workman suspended from the new wires in a bo'sun's chair. The position of the man dangling at such a height over mid street from a wire of such comparatively slender proportions has the appearance of being a hazardous one, but owing to the precautions taken the danger is perhaps no greater than that to pedestrians exposed to the risks of traffic in the streets below.

London was no exception to the rule, first followed almost universally, that earth return circuits, in contradistinction to metallic circuits, for subscribers' lines were employed. Single circuits continued to be provided from the time the Telephone Co., Ltd., commenced to dispense exchange service until the conversion of the existing single lines into metallic circuits became a matter of absolute necessity, when, in view of the huge growth of the number of subscribers, the engineers of the National Telephone Company were faced with a task of considerable magnitude. The work of return circuiting the subscribers' lines in the Metropolitan area was commenced in 1890, and completed in 1895.

The London County Council Subways Act, 1893, had an important bearing upon the provision of underground plant for telephone purposes. Its object was to limit the breaking up of or disturbance to the streets, within the administrative County of London, caused by the installation and maintenance of underground works of various descriptions, by compelling the various administrations concerned to make use of the subways belonging to the County Council, in preference to the indiscriminate laying of mains of all classes, hitherto the cause of frequent interference with the

FIG. 81.—Renewing Aërial Cable Suspenders in Mid Air, London, 1909.

(From a photograph by Mr. C. A. Jackson.)

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FIG. 82.—Subway, Victoria Embankment, London, W.C., showing telephone cables.

(From a photograph.)

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permanent surface of the streets. The preamble of the Act was as follows :—

" Whereas subways under certain streets in the Administrative County of London have been constructed by the London County Council or the Metropolitan Board of Works, and are now vested in the London County Council. And it is expedient to make provisions to secure the more effectual use of such subways so as to limit the breaking up or interference with the streets and that further powers with respect to such subways should be conferred upon the Council as in this Act set forth."

The provisions of this Act very largely limited the disturbance of the paved surface of streets by operations of companies possessing any power or right of usage of streets for accommodation of mains or services, to that caused by the provision of lateral connections between the subways and neighbouring side streets or premises, to the removal of pipes or wires into the subways, and in giving attention to existing mains not removed into the subway.

The Act provided, in certain circumstances, for removal of existing pipes and wires into the subways, the reasonable cost so incurred to be borne by the Council.

The Council were empowered to make charges for using subways according to a determined scale, and to enforce bye-laws in regard to their general use, the constitution and relative position of the various mains accommodated and the control and regulation of persons resorting to them. The requirements of the Board of Trade and of the Post Office were safeguarded. Mains of all descriptions were, and still are, accommodated in the subways of the London County Council, including gas, water, hydraulic, telegraph, telephone and electric light and power mains. Fig. 82 is an illustration of a portion of a subway situated in Victoria Embankment near Blackfriars Bridge, and is from a photograph taken in 1909.

Upon the appointment, in 1892, of Mr. Dane Sinclair as engineer-in-chief to the company, the London managership was undertaken by Mr. Augustus Calder, and in 1893, when the position of superintendent was created, Mr. Calder became Metropolitan superintendent. On his death, in 1896, Mr. Charles Butler Clay, then superintendent for the Southern and Western Provinces, assumed control of the Metropolitan area, and continued as Metropolitan superintendent until the transfer to the

State of the company's undertaking at the end of 1911. Mr. Clay's name has been mentioned several times in this volume, first in association with the United Telephone Company in London and afterwards as general manager for the Northern District Telephone Company. He was one of the pioneers of the telephone in this country, and his name is indelibly associated with telephone development in the provincial areas mentioned, and in London. Mr. Clay is possessed of a fund of reminiscence and anecdote, and upon the former he has kindly drawn, at the author's request, in contribution to the pages of this volume.

When the Bill, which eventually became the Telegraph Act, 1892, was before Parliament, the directors of the National Telephone Company were hopeful that, by its enactments, they would be given the statutory powers they were anxious to obtain to enable them to secure consent for the installation of underground plant, but when the Bill became law the position, in that respect, was in no wise improved. Local authorities still controlled the situation, and were in a position to prevent the National Telephone Company from laying underground works or to make their consent contingent upon any stipulations and charges which they thought fit to impose. In order to overcome this difficulty, an arrangement was made between the Postmaster-General and the company by which the Post Office, if they approved, should provide for the company, on certain terms, underground pipes and wires required in the interests of the telephone service, which they were in a position to lay for them under the provisions of the Telegraph Act, 1863.

In April 1896, or thereabouts, the National Telephone Company applied to the Commission of Sewers, who at that time constituted the highway authority for London, for permission to place pipes and wires under certain of the London streets; despite the strenuous endeavours of the company to bring the matter to a satisfactory conclusion consent was refused except under certain stipulations, one virtually to the effect that the Commissioner of Sewers should dictate the rates to be charged by the company for telephone service in London. The National Telephone Company thereupon applied to the Postmaster-General to lay for them the pipes and wires they required. The Postmaster-General complied, and subsequently made over to the company the use of certain pipes on the agreed terms, without apprising

the Commissioners of Sewers of his action. As soon as the Commissioners of Sewers discovered the trick, for so apparently they regarded it, which had been played upon them they gave notice to the Postmaster-General that their refusal to give consent to the company for laying pipes and wires was in consequence of the disinclination of the company to make any concessions for the public benefit, either by providing an improved telephone service, or by reducing its charges; also that they (the Commissioners of Sewers) objected to what the Postmaster-General had done without their consent. Subsequently, in giving consent, in respect of a later application, made by the Postmaster-General, for laying underground works in London, the Commissioners of Sewers, apparently chagrined at what had transpired, attached to the consent a stipulation that the line of telegraphs covered thereby should not be " laid for the use of the National Telephone Company unless the latter were prepared to provide an improved service at a reduced cost." The Postmaster-General objected to this condition, and the matter was brought before Mr. Commissioner Kerr, who decided that the condition ought not to be attached to the consent of the Commissioners, and ordered that the Postmaster-General should be at liberty to place and maintain the line or lines of underground telegraphs as described. The Commissioners of Sewers gave notice of their desire that the difference should be referred to the Railway Commissioners, in accordance with section 4 of the Telegraph Act, 1878; accordingly, the case was heard by the Railway and Canal Commissioners at the Royal Courts of Justice on Thursday, February 10th, 1898.

The Solicitor-General for the Postmaster-General contended that the condition was unreasonable; the local offices were worked under licence of the Postmaster-General, and the whole was one working system, as contemplated under the Act of 1892, when the trunk lines were acquired; the position was absurd, inasmuch as the Commissioners of Sewers objected to the wires being laid unless the Telephone Company were prepared to provide an improved service at a reduced cost in accordance with the evidence given before a Select Committee of the House of Commons in 1896. That Committee had not reported, and the Corporation were asserting a right to take into their own hands the enforcement of what they considered the effect of the evidence given before the Select Committee, and to determine the reasonableness

of the charges and conditions under which the telephone service was to be carried on.

Judgment with costs was given for the Postmaster-General; the court held that the Commissioners of Sewers' objection was an unreasonable one and that as road authority the objection did not concern them—in other words, they were to mind their own business.

A similar case, in which the Glasgow Corporation was concerned is referred to in Chapter IX.

The Telegraph Act of 1892 authorised the Postmaster-General to delegate to his licensees the same powers which he possessed under the Telegraph Acts, but subject to the consent of the local or other public authority. Although the National Telephone Company was unable to come to terms with the London County Council in respect of wayleave for the installation of underground plant, nevertheless it opened up negotiations with certain of the vestries and district boards in the County of London with the object of securing their consent. This consent in some cases was forthcoming, the company proceeded to act upon it and in due course certain underground plant was actually laid. The London County Council, becoming aware of what had transpired, informed the various vestries that the Council's consent had not been obtained as required by the Telegraph Acts, and requested that they should be immediately informed, should the company commence any works in their respective districts.

On October 31st, 1899, the Secretary of the Post Office issued a circular to the clerks of vestries and district boards informing them that the National Telephone Company had no power, either with or without the consent of the road authority, to take up streets save when endowed by the Postmaster-General with authority to exercise certain powers of construction conferred by the Telegraph Acts, and that it possessed no statutory powers. By the agreement for purchase of the company's trunk lines dated March 25th, 1896, the Postmaster-General had agreed to give the company, from time to time, such authority as was provided for in the Act, under certain provisos. No authority had as yet been conferred by the Postmaster-General upon the company to exercise powers of constructing telegraphs in any part of the County of London. Until the company was endowed with the authority of the Postmaster-General, and had obtained the con-

sent of the London County Council to the exercise of the powers conferred by the Postmaster-General's authority, it committed a nuisance, and was liable to legal proceedings if it disturbed any street in London, even though it had come to an arrangement with the road authority on the subject.

The general manager of the company, Mr. W. E. L. Gaine, retaliated by notifying the forty-one London local authorities that, according to the views held by the directors of the company, the Postmaster-General was under an absolute covenant to delegate his powers to the company whenever called upon by the company so to do. He pointed out that under the Telegraph Act, 1892, the Postmaster-General was empowered to delegate to any licensee any of his powers contained in the Telegraph Acts for breaking up streets, but in the Metropolitan area these powers could only be exercised with the consent of the London County Council and of the road authority of the district. As the company had been unable to secure the consent of the London County Council, it had not hitherto called upon the Postmaster-General to exercise his powers.

The London County Council considered the matter at some length on February 13th, 1900, and their solicitor was instructed to initiate proceedings against the company for having infringed the provisions of the Telegraph Acts.

In return for the wayleave facilities they desired to secure from the London County Council, the company offered to supply service at the same rates, and upon the same terms, as the Post Office, but flatly declined to agree to the stipulation made by the Highways Committee of the County Council that they should give free intercommunication between its London subscribers and those of the Post Office. This question of intercommunication was an important matter for the Post Office and its prospective subscribers and appeared to be a valuable weapon in the hands of the National Telephone Company. Without intercommunication, the Post Office subscribers would be able to communicate with one another only, and would be entirely debarred from communication with the large body of subscribers already connected to the company's system. Without such intercommunication, the development of the Post Office system would be greatly prejudiced, while, on the other hand, that of the company's system would be favourably influenced. In answer to a question put in

the House of Commons early in March 1900 relative to the progress made by the Post Office with the construction of its London system, Mr. Hanbury stated that " there was no power to compel the company to allow intercommunication between their exchanges and those of the Post Office, but in view of the great importance to the public of such intercommunication all reasonable steps would be taken to effect it, and the co-operation of the London County Council as the chief road authority might be of considerable assistance in bringing about that desirable result."

Mr. W. E. L. Gaine, in a circular addressed to members of the London County Council wherein the company's case was stated, likened the demand of the Council for free intercommunication by a competitor commencing business as equivalent to asking that a new railway a few miles long should have free running powers over the whole of the London and North-Western Railway system.

Proceedings were eventually instituted by the Postmaster-General to restrain the company from breaking up the streets of London without his licence, and on March 16th, 1900, the case was opened by the Attorney-General before Mr. Justice Grantham and Mr. Justice Phillimore. It was postponed by arrangement, and was not ultimately decided until July 24th, 1900, before Justices Darling and Kennedy, sitting in the Queen's Bench Division. The company contended that in what they had done they had been acting within their legal rights. After brief consultation between counsel, a settlement was arrived at and eventually agreed to by the Court. The terms of the settlement were :—

(1) A declaration that the defendants were not entitled to lay any pipes, wires, cables or apparatus for telephonic purposes under any of the streets of the County of London, unless by licence of the Postmaster-General, under the Telegraph Acts, and with the consents required by those Acts.

(2) An injunction restraining the defendant company, their officers, servants and agents, from opening or breaking up any street or public road within the meaning of the Telegraph Acts, 1863 to 1899, within the administrative County of London or any part of such street or public road, for the purpose of extending the company's present system of underground pipes, wires, etc., without the authority of the Postmaster-General, and the

consent of the London County Council for such purposes described by the Telegraph Act, 1892, and,

(3) The defendant company to pay the taxed costs.

The company's position respecting the installation of underground plant in the County of London was thus made clear.

On November 18th, 1901, the Postmaster-General entered into an agreement with the National Telephone Co., Ltd., for the purchase of the plant of the company in the London exchange area. The purchase was to take effect on December 31st, 1911, and was to be made on "tramway terms," *i.e.*, the plant was to be purchased at its value *in situ*, and no payment was to be made in respect of compulsory purchase, good-will or past or future profits. The agreement also provided for intercommunication between the system of the company, and that of the Post Office, about to be established, during the remainder of the company's tenure of licence, and for uniformity of rates. This agreement was in effect approved by the House of Commons after full discussion on January 27th, 1902. The circumstances attending its completion are more fully related in Chapter XXI.

TELEPHONE NUMBERS ALLOTTED TO EIGHTEEN METROPOLITAN TELEPHONE EXCHANGES PRIOR TO 1895

Name of Exchange.	Numbers allotted	
	From.	To.
Coleman Street	1	500
Leadenhall	501	1000
Cornhill	1001	1500
Queen Victoria Street	1501	2000
Mincing Lane	2001	2500
Chancery Lane	2501	3000
Westminster	3001	3500
Heddon Street (later Regent and then Gerrard)	3501	4000
Avenue	4001 11,001	4500 12,000
Hop	4501	5000
East	5001	5300
Shadwell	5301	5400
Stratford	5401	6000
Albert Docks	6001	6500
Smithfield	6501	7000
Edgware Road	7001	7400
Kilburn	7401	7500
Gloucester Road (later Kensington)	7501	?

For some considerable time after the establishment of telephone exchanges in London, exchanges were not identified by name for calling purposes, and subscribers were not therefore expected to give the name of the exchange, as well as the subscriber's number, when stating their requirements. Blocks of numbers were allotted to the different exchanges, and for each call the operator had to determine the exchange to which it should be passed. Mr. W. B. Benham, of the London telephone service, has kindly supplied, from memory, the numbers indicated in the schedule on p. 251, at one time allotted to eighteen of the London exchanges, together with other information regarding the early London exchanges.

There were also exchanges at Clapham, Balham and Battersea, but the numbers allotted to them cannot be recalled.

With such a high proportion of junction calls as always appertained to the Metropolitan telephone service, this system, whereby recognition by subscribers of exchanges was avoided by the allotment of groups of numbers to the several exchanges, was particularly trying to the operators; moreover, owing to frequent changes, the numbering of the multiple was subjected to disturbance. In course of time, several exchanges were merged into others, a number of them, for example, into Avenue, the numbering of the subscribers' multiple at this exchange ultimately reading as below: —

64	65				
31	32	60	61	62	63
25	26	27	28	29	30
~~114~~	~~115~~	116	~~117~~	~~118~~	~~119~~
43	44	~~120~~	~~121~~	~~122~~	~~123~~
22	23	24	40	41	42
11	12	13	14	20	21
5	6	7	8	9	10

The system was abandoned and each exchange renumbered from one upwards in about 1895. When the change was effected, certain modifications were obviously necessary in the arrangement of the multiple, and the deletion of certain digits took place, as indicated by the figures struck out in the above diagram of the multiple numbering of the Avenue Exchange. The example quoted well illustrates the difficulties experienced by operators in finding numbers in the multiple without long practice and association with it.

The considerations relating to the introduction and development of the common battery system in the United Kingdom receive general treatment in Chapter XIII. The first common

battery exchange to be opened in London and the third in the United Kingdom was Kensington in December 1901. Thereafter the common battery system expanded rapidly and the magneto system, which it replaced, correspondingly waned. The growth of the common battery system and the accompanying

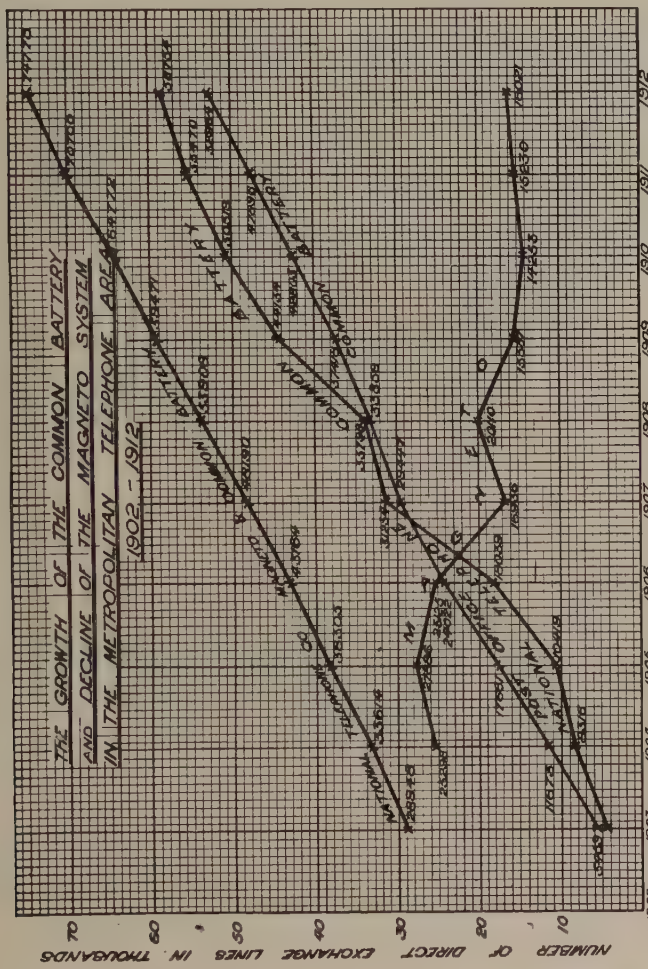

Fig. 83.—Growth of the Common Battery and decline of the Magneto System in the Metropolitan Area, 1902–1912.

decline in the magneto system in London are illustrated graphically in Fig. 83. Particulars of the 21 common battery exchanges opened by the National Telephone Company in the Metropolitan telephone area from 1901 to 1912 are given in Table No. 6.

The magnitude of the Metropolitan telephone system was responsible for the introduction of problems of a more momentous

nature than those met with in less populous and congested areas. Operations of a large and sometimes an extensive character which affected all classes of telephone plant had to be performed more or less frequently and were rendered all the more difficult because of the necessity for avoiding interruption to the service. The large number of circuits often involved added considerably to the difficulties met with in such cases. One such important problem presented itself when the common battery system was first introduced, and in London, where the use of that system extended rapidly, it became one of no small significance and was accorded particularly careful attention. Not only did the introduction of the common battery system involve the transfer of large numbers of subscribers from an old to a new exchange, an operation in itself requiring very careful handling, but it was accompanied by a radical change in the system of working, a feature which increased considerably the delicacy and intricacy of the operation.

Experience gained in London with the first few transfers undertaken, coupled with careful study of the problem, had the effect of reducing almost to a fine art the delicate and costly operation of simultaneous transfer from one switchboard to another, and conversion from one system of working to another, and several feats of scientific organisation and management were accomplished during the period of transition from magneto to common battery working in London, and also incidentally in the provinces. To safeguard the interests of the telephone using public in securing immunity from faults during the process of transfer and to preclude all possible interruption to the service, the policy of effecting the transfer of the whole of the subscribers concerned, often amounting to several thousands in number, simultaneously in a few seconds, was adopted.

It is not intended to describe here the measures taken in effecting such huge and complex removals; that has already been done and the problem generally discussed in a paper entitled "Telephone Exchange Transfers and their Organisation," read by the author before the Institution of Electrical Engineers in London, on January 24th, 1918.

The list in Table No. 6 shows the exchanges which required treatment of a more or less involved character such as that mentioned. The transfer of Gerrard was the largest of its kind accomplished in London. On this occasion no fewer than 20,000 telephone stations were concerned. In all, roughly 12,000

working circuits had to be handled; of these nearly 7,000 were subscribers' direct exchange lines and 1,500 were junctions. The operation of disconnecting from the old exchange and connecting to the new common battery equipment was successfully accomplished in the space of 14 minutes. Similarly delicate, though perhaps less involved, operations accompanied the opening of the other common battery exchanges included in the list.

Consequent upon the recommendations of the Select Committee appointed by the House of Commons on May 9th, 1918, the Post Office opened telephone service in London in competition with the National Telephone Co., Ltd., in March 1902. The activities of the Post Office in this connection are referred to in greater detail in Chapter XV. By this step on the part of the Government, the company was bereft of a large portion of the field they hitherto possessed for conducting profitable telephone business in London and the contiguous territory. Prior to this date, the company were prevented from developing to the utmost the telephone service in London by the absence of facilities for the installation of underground plant, and by the tremendous difficulties encountered in connection with its overhead line system.

Telephone development by the company was thus curtailed; the Post Office, however, suffering under no such disability, and provided by the Telegraph Acts with the requisite Parliamentary powers to enable them to instal and maintain in public thoroughfares the plant required for telephone purposes, were enabled to proceed without hindrance. The accelerated development which accrued from the active participation by the Post Office in the telephoning of London is illustrated in graphical form in Fig. 186.

The organisation of staff in an area of such large extent and, with such varying requirements as the Metropolitan telephone area was a matter which could not be treated lightly when the use of the telephone began to be at all popular. When, through the expansion of the telephone service, the need for some consistent organisation arose, an arrangement was adopted somewhat similar to that already mentioned as brought into force in the provinces, the Metropolitan area being treated as a Province. The Metropolitan area was placed under the control of a Metropolitan superintendent, and managers, responsible to him, were appointed to take charge of the several districts into which the area was divided; there were six districts, namely, City, West, South, East, North and Croydon.

The increasing amount, variety and complexity of the plant, and the consequent multiplication of duties to be performed, led to the adoption of a policy which had for its basis specialisation by experts in the different branches of the telephone profession, and an organisation of staff providing for a complete scheme of functional working, based on the American plan, for the whole of the Metropolitan area, was eventually introduced in January 1905. The old districts were abolished, and, under the supreme control of Mr. Charles Butler Clay, the Metropolitan superintendent, the Metropolitan area was administered in close co-operation by officers whose designation was as follows :—

1. Metropolitan Engineer.
2. Metropolitan Electrician.
3. Metropolitan Traffic Manager.
4. Metropolitan Contract Manager.
5. Metropolitan Chief Accountant.
6. Metropolitan Stores and Workshops Manager.

Under these officers the territory was suitably divided, each division being placed under the management of officers acting in co-operation under their respective heads. The arrangement of staff in the Metropolitan area as it existed, with slight varying modifications, from the time of its introduction to 1912, is indicated in the staff diagram shown in Fig. 84.

For some considerable time after the introduction of telephony on commercial lines it was not usually difficult to secure premises suitably situated and sufficiently capacious for the satisfactory accommodation of exchange plant, but as the telephone business grew the provision of premises became a more important problem. The increased space necessary for large multiple switchboards and for accommodation of the staff to work them, the necessity for leading in circuits underground at greatly enhanced capital cost, the desirability of suitably providing for extension of the exchange plant as occasion demanded owing to growth of the service and the acquisition of a situation centrally placed in relation to the position of the subscribers to be served, were important considerations, as also was the question of continuity of tenure. These, with other minor considerations, led the directors of the National Telephone Company, in 1897, to adopt the general policy of erecting buildings specially designed and constructed for the purpose. It was sometimes possible, however,

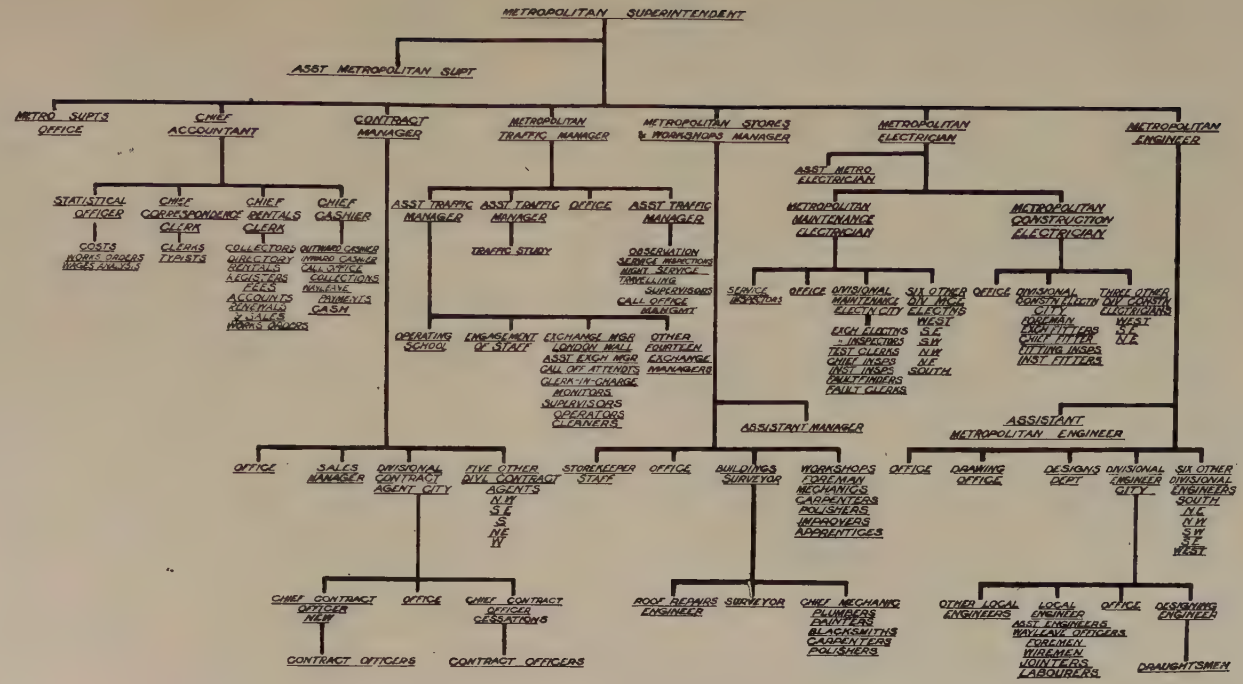

FIG. 84.—The National Telephone Company's Metropolitan Staff Organisation, 1905–1912.

to secure a building suitable for adaptation to the requirements of an exchange. Buildings originally used as places of worship, public halls, private residences, and places of business, clubs and the like have variously been considered, and in some cases adapted to the requirements of large telephone exchanges.

The building which houses the National Telephone Company's "North" Exchange, situated at 113 Bride Street, Barnsbury, London, possesses special historic interest relating, not only to telephony in particular, but also to electrical science in general. The building was at one time used as a chapel, and was purchased by the company in 1899, the new common battery exchange being eventually brought into service on December 17th, 1904. Upon its acquisition, through the instrumentality of Mr. B. S. Cohen, it came to light that, between 1862 and 1899, the building was used as the Barnsbury Grove meeting house of the Sandemanians, of which body Michael Faraday was an elder. It transpired from inquiries set on foot that Faraday regularly attended the meetings held there, from the time of the erection of the building in 1862 almost to the time of his death.

This circumstance was suitably commemorated by the unveiling by Lord Kelvin of a bronze memorial tablet on which appeared the following inscription :—

ERECTED BY THE
STAFF OF THE
NATIONAL TELEPHONE COMPANY LIMITED
TO COMMEMORATE THE FACT THAT
MICHAEL FARADAY USED TO WORSHIP HERE
FROM 1862 TILL THE DATE OF HIS DEATH IN 1867.
FROM 1862 TO 1899 THIS BUILDING WAS
THE MEETING HOUSE OF THE SANDEMANIANS
OF WHICH BODY MICHAEL FARADAY WAS AN ELDER.
THIS PLATE MARKS THE POSITION
WHICH HE USUALLY OCCUPIED ON THE PLATFORM.
THE POSITION OF HIS PEW IS INDICATED BY
A PLATE IN THE FLOOR.
UNVEILED BY THE
RIGHT HON. LORD KELVIN, O.M., P.C., G.C.V.O., F.R.S., LL.D.,
ETC.
24TH NOVEMBER, 1906

Sir Albert K. Rollit, LL.D., presided over the proceedings on behalf of the directors of the National Telephone Company, and other speakers were as follows :—

Mr. C. B. Clay,
Lord Kelvin,
Mr. F. Gill,
Sir Joseph Swan,
Dr. Silvanus P. Thompson.

A full account of the ceremony is recorded in the *National Telephone Journal* for January 1907. The remarks made by Lord Kelvin, who was intimately associated with the telephone, and closely acquainted with Faraday, are of particular interest and are therefore quoted in full from the *National Telephone Journal* as follows :—

" It is indeed a crowning privilege of my life to assist to-day in the anauguration of this monument of Faraday. Sixty-six years ago his was the inspiring influence of my early love for electricity. I did not then know him except in his published scientific papers. Ten years later I heard him lecture in the Royal Institution, and I had the great honour of making his personal acquaintance. For many years after 1850 my chief attraction for making a journey from Glasgow to London was always a visit to the Royal Institution to see Faraday—at home in the midst of his work. Bright, lively, kind, he showed me what he was doing. He spoke to me of it, and he encouraged me to go on with any work I could take up, either in connection with electricity or any of the other interesting and important things in physical science in which he was working and making discoveries. His encouragement to me was, indeed, most valuable. I treasure it now, and I can look back upon it as an inspiring influence throughout my life. Faraday had the gift of inspiration. Clerk-Maxwell, Helmholtz, Hertz, all took their lead in electrical discovery from Faraday, and much of what has been accomplished by them has resulted from his work and influence. Take only one case—one of the numerous applications of electricity for the good of mankind—wireless telegraphy. That came straight from Faraday and his American colleague in electrical discovery—Joseph Henry—who, simultaneously with Faraday, made some of the vast advances in knowledge, which followed quickly from Oersted's primary discovery of electromagnetism. Faraday and Joseph Henry regarded one another with mutual respect and admiration, though I do not think they actually ever met.

" To-day we have inaugurated a memorial tablet to Faraday, and here in the building in which it is placed we may well repeat the celebrated Latin words—*Si monumentum requiris, circumspice*, which are inscribed in St. Paul's Cathedral over the tomb of Sir Christopher Wren. Look around. In the place itself you see a monument of Faraday. These walls tell a story, not of a magnificent cathedral, but of the humble Meeting House of earnest Christian men. Here were carried on the religious services of the Sandemanians in London, a very simple association devoted to faithful and earnest Christian work. Throughout his life Faraday adhered faithfully to this denomination as an officiating elder. Whatever occupied him throughout the week, every Sunday he wended his way to his chapel—not in early years to this particular building, but to one in Barbican, in the City of London. He went there regularly every Sunday, and for the last five years of his life every Sunday that he was in London he came to this place. When away from London he sought his Sandemanian brethren whenever possible. I well remember, at meetings of the British Association in Aberdeen and Glasgow, how he sought out the meetings of his denomination and spent, as a preacher or worshipper there, the Sunday and any time that he could take away from the work of the association. How very interesting it is to think of Faraday's lifelong faithfulness to his religious denomination. In another sense it is of very great interest to us to look around in this place and see the busy telephone operators doing their daily work in it. This also is a splendid monument to Faraday. Every electrician present, and all who are engaged in the telephonic business, will heartily agree with me in admiring and wondering at this beautiful and useful result of the vast discoveries in electro-magnetism in which Faraday led the way. How much Faraday would have been delighted with the telephone, some of us can imagine. It was quite unknown to him, but with what intense delight and extreme interest he would have regarded the discovery if he had lived to see it, we can imagine.

" How much, too, would he have delighted in the applications of electricity to the transmission of power! Holmes had made a large, powerful magneto-electric machine (we call it dynamo now) and brought it to Faraday. He had learned the possibility of such a machine from Faraday, who said to him: 'I gave it to you as a baby, and you have brought it back to me a giant.' How many other practical applications of electrical science have grown up from Faraday's work is now well known to the world.

" Looking upon the monument inaugurated here to-day, we feel a debt of gratitude is owing to the staff of the National Telephone Company for what they have done in religiously preserving the memory of Faraday's attendances in this place during the last five years of his life. It is of extreme interest to

me to look back to the early days of the telephone before, nominally, the National Telephone Company came into existence; and to look back also on the many years which have passed since the National Telephone Company entered on its work, and began to form the grand organisation which it now maintains and controls. It has been a great pleasure and honour to me to have been officially connected with the National Telephone Company for many years; I now congratulate them on the great success which has attended their persevering activity. The telephone business which they have created will, in a few years, be taken up and continued by the Government in the interests of the nation. Nothing could be more desirable than such a mode of immortalising the practical life and work of the National Telephone Company. It hands over its material and the good will of its staff to the Government to work for the public good throughout the British Isles."

In conclusion, Lord Kelvin said he would ever remember the kindliness of Faraday, his fertilising influence throughout the scientific world, and the encouragements which he extended to any attempt to apply mathematical demonstration to the problems of science, which were the subjects of his daily work so long as health and life allowed him.

The telephone industry thus possesses a very close link with the personality of Faraday, and the memorial referred to happily associates those two great scientists, Faraday and Kelvin.

Another building used for telephone purposes in London is of passing interest. This was a building previously known as the Pelican Club, situated in Gerrard Street, acquired by the National Telephone Company in about 1894, for the purpose of housing the Gerrard Exchange. In the basement of this building prize fights and cock fights were wont to be conducted, and holes in the floor, where, at one time, were fixed the posts for supporting the rope forming the ring, were visible during the time the building was used as a telephone exchange.

The two London exchanges, Brixton and Sydenham, are housed in buildings not specially designed for the purpose. These buildings, originally known as Gresham Hall and Sydenham Hall respectively, were at one time used for concerts, dances and the like and were admirably adapted to serve the purpose of a telephone exchange.

The London Wall Exchange is one of the largest and the busiest of the London exchanges, and is the present day memorial

of the original London telephone exchange, situated at 36 Coleman Street, E.C., from which it developed. Situated at the commercial hub of the Metropolis, London Wall, it is unique in the arrangement of its switchboard. Floor space in the City of London is extremely valuable, rentals which, in other places would be reckoned fabulous, are readily paid by firms whose business compels them to occupy premises in that quarter. The building space available for the switching equipment at London Wall was extremely limited, and, in order to secure sufficient accommodation for a 10,000 line exchange in the circumscribed space available, the switchboard was divided into three distinct portions; each was placed in a separate gallery, an uncommon arrangement which gives the exchange an unusual appearance. The lower gallery accommodates the incoming junction sections and the subscribers' sections are situated in the two upper galleries. This exchange was opened for service on January 28th, 1905, under the calamitous circumstances presently to be related. It was described and illustrated in the *Electrician* for April 21st, 1905.

Probably the elements most dreaded by the telephone engineer and the worst enemies the telephone possesses are fire and water, including the storms of snow which sometimes wreak such havoc with telephone line plant during the winter months.

Owing to the elaborate precautions taken against fire, particularly in comparatively modern times, serious fires in telephone exchanges have, fortunately, not been of common occurrence, but in the history of the London Fire Brigade are included several fires of serious dimensions which occurred in telephone exchanges, and others which affected seriously overhead telephone plant.

Amongst the more serious objections to the use of overhead line plant in London was the disturbance to the telephone service which frequently ensued after a serious fire, owing to the burning out and sometimes complete destruction of overhead line plant which existed over and in close proximity to the conflagration. In addition to the dislocation of the telephone service, falling wires were a possible source of danger to the public and a serious menace to the fireman, whose movements were likely to be hampered by the masses of cables and wires which in many places existed. Close relationship existed between the London Fire Brigade and the engineers of the National Telephone Company, who were frequently amongst the first to be apprised of a conflagration

in order that a responsible officer might attend with the necessary workmen for the purpose of taking whatever precautions the exigencies of the situation demanded, in the opinion of the Fire Brigade superintendent. The inflammable nature of the aërial cables distributed over the house-tops of London, particularly in the City and West End, was a factor to be contended with, and in order to prevent the spread of fire from one building to another by burning cables, it has sometimes been necessary for workmen to be dispatched aloft in the fire and smoke, to cut away fiercely burning cables from the adjoining roof supports.

During the evening of June 16th, 1898, a serious fire occurred at Burlington Buildings, Heddon Street, London, which supported a massive derrick carrying a large number of open wires and rubber-covered cables. With the collapse of the roof, the heavy telephone structure, weighing many tons, was pitched bodily into the street where it lay until cleared away, a tangled mass of iron-work, wire and cable. A large number of telephone circuits were interrupted, and the work of restoring the service to those subscribers deprived of it was an example of the expense and nuisance which might have been avoided had the means for provision of underground lines been previously available.

London Wall was the scene of a most disastrous fire which occurred in the evening of July 9th, 1902. It broke out in the London Wall Exchange after the usual hours of attendance of the engineering staff, and before midnight the exchange was completely burnt out, and the building entirely gutted. Fortunately for the 2600 subscribers whose service was so disastrously severed, the offices adjoining were in the occupation of the National Telephone Company, and a very smart piece of work was accomplished by the company's engineering staff under the direction of Mr. C. B. Clay, the Metropolitan superintendent. The company held in reserve for purposes of emergency, such as the one in question, exchange equipment and materials at their Nottingham factory. This was immediately requisitioned by telephone and was delivered at London Wall on the following day. Meanwhile, steps had been taken to secure other suitable accommodation for the staff occupying the premises adjoining those destroyed by the fire, and they were immediately transferred. Expert exchange fitters, jointers and other skilled workmen were telephoned for from various parts of London and the provinces, and

the work of installing the new plant proceeded continuously both night and day. The work involved in such a contingency can only be fully appreciated by those possessing actual experience of such emergency conditions. The overhead cables entering the exchange were entirely destroyed, and the ends of the underground cables in the basement were damaged by fire and water and falling *débris*. One hundred new aërial cables, together with the necessary standards and the girders for their support, and over 420 miles of external wiring were erected. So excellent was the organisation and the work performed, that full service was restored to the whole of the subscribers affected within the remarkably short period of 16 days. The cause of the fire was never discovered.

The London Wall Exchange was particularly unfortunate in the matter of destructive fires, for on January 27th, 1905, less than three years after the fire referred to, a second serious fire broke out in the test-room of the exchange. Fortunately, it was immediately discovered, and confined to the apparatus-room, where, however, irreparable damage was done to the equipment. The Metropolitan staff were more fortunate in this case than in the previously mentioned fire, for during the preceding months the installation of a new common battery exchange had been proceeding in premises adjoining those in which the fire occurred, and fortunately again the new equipment was almost ready for service and the transfer arrangements were well advanced. The fire precipitated the transfer, and by almost superhuman efforts it was accomplished during the night; the working lines, which comprised 3819 subscribers, 1060 junctions and 1080 miscellaneous circuits, were giving satisfactory service in time for the business of the day following the fire. Again the cause of the fire was not discovered.

In the absence of facilities for the provision of underground work within the public thoroughfares, arrangements were made by the company to make use of some of the underground railways and tubes for the accommodation of cables, the Metropolitan Railway and the City and South London tube being notable in this respect. A fire which broke out simultaneously in the Bank Exchange situated in Queen Victoria Street and the test-room at Oxford Court, Cannon Street, a month after the last mentioned London Wall fire, *i.e.*, on February 28th, 1905, proved

to have been caused by a contact between one of the company's lead-covered cables and the live rail in the Underground Railway at Westminster Bridge Station. This contact was caused by a length of metal troughing used for the accommodation of cables on the underground railways either becoming dislodged from its normal position and falling across the live rail and the company's cable, or being carelessly left in such position by a workman. The two test-rooms were entirely burnt out, with the result that 2208 subscribers were deprived of their telephone service, and 2078 working junction connections severed.

A feature associated with the restoration of service at the Bank Exchange in this case is not without interest. In reterminating the damaged dry core cables on the test frame of the Bank Exchange, the usual pothead or silk and cotton terminating cables were omitted, the ends of the paper insulated wires, after suitable treatment with beeswax, being directly connected to the soldering tags of the protective apparatus. It was not intended that these cables should remain indefinitely in this condition, but that they should be terminated in standard manner at the earliest available opportunity. The insulation was, however, found to remain at a sufficiently high level for satisfactory working and the paper core terminations were therefore retained and actually exist at the date these pages are penned.

The Bartholomew House telephone exchange was and still is one of the telephone peculiarities of London, and was originally provided to serve a special purpose. It was specifically intended to give stockbrokers facilities for direct communication one with another, and with the Stock Exchange, apart from the usual public exchange system with which facilities for intercommunication were not provided. It was the property of the Exchange Telegraph Company, the requisite plant being provided and maintained by the National Telephone Company. The subscribers were not strictly confined to Stock Exchange members, and others whose business was closely allied with Stock Exchange movements were connected. The service was instituted originally by the Exchange Telegraph Company, as an adjunct to the tape telegraph machines, the distinctive feature of that company's service, but at a later date the telephone service became more or less dissociated from the telegraph service and telephones alone were supplied if required.

The rates were as follows :—

Class A service : £50 4*s.* 0*d.* per annum. Tape instrument, Bartholomew House exchange line and use of Stock Exchange call offices.

Class B service : £25 0*s.* 0*d.* per annum. Bartholomew House exchange line and use of Stock Exchange call offices.

Class C service : £12 10*s.* 0*d.* Use of Stock Exchange call offices only.

One of the special requirements of the Stock Exchange business is rapidity of communication between its members, and the telephone stands unrivalled in supplying such facilities as were required. The method of operating the traffic was particularly suited to give the utmost rapidity of connection ; special arrangements were made whereby a Bartholomew House subscriber might actually get quickly into telephonic communication with his own, or another firm's, representative, present in the Stock Exchange. In 1911 there were over 400 subscribers to this exchange.

In many of the large cities and towns of this country the practicability of the telephone was first demonstrated by the transmission of music from some suitable and conveniently situated source, frequently an organ, to a distant point, where a number of Bell receivers, or even an Edison loud speaking receiver, were provided, by means of which the distant music was reproduced for the benefit of those assembled. Perhaps at this time it was not appreciated that the telephone would ultimately become the universal means of providing intercommunication it has become to-day. The transmission of music seemed particularly to appeal to the general public, and therefore, as was desired, served as an excellent advertisement.

It will, no doubt, be remembered that the transmission of music was attempted before that of speech, and that, as long ago as 1861, the electrical apparatus invented by Phillip Reis, a German electrician, was capable of transmitting musical sounds.

The great use subsequently made of the telephone for transmission of speech eventually eclipsed the transmission of music, and the demonstrations which at one time were of somewhat common occurrence practically ceased. In certain towns, however, lines connected to theatres and churches were maintained and arrangements made whereby subscribers might listen, by

means of their ordinary receivers, to an opera or church service. Where the demand for such facilities was encouraging, more elaborate arrangements were made and in this way what is known to-day as the " Electrophone " service came into being.

Among the first practical attempts to transmit music by telephone was one in 1883, when the play " La Mascotte " was transmitted from the Comedy Theatre to 120 receivers situated in the Hotel Bristol. The demonstration lasted for a period of five nights.

In 1891, theatrical performances in London were successfully transmitted to Birmingham, and received by guests assembled in the Midland Institute.

In Paris, the so-called " Theatrephone " had been established and popularised for the purpose of transmitting music from theatres and concert halls to selected places, and on January 10th, 1892, as a trial, a room set apart as a music-room during the Electrical Exhibition at the Crystal Palace was fitted with the necessary appliances for the reception of music. The music of performances at the Lyric Theatre in London, and at theatres and concert-rooms in Birmingham, Liverpool, Manchester and other places, was transmitted with entire success, a large number of visitors availing themselves of the unusual facilities. The music-room remained in operation for six months and nearly 60,000 people were recorded as having paid it a visit. The charge made was 3*d*. before and 6*d*. after 8.0 p.m. for ten minutes' hearing.

Facilities were afforded to subscribers to the National Telephone Company's system in the Metropolitan area to have transmitted to them musical performances, public speeches, church services, etc., by the formation of the Electrophone Company in 1894. This company worked by arrangement with the National Telephone Company, and agreements were made with the proper authorities for the installation of the necessary apparatus and lines in a selection of theatres, churches, music halls and other places, and a regular electrophone service was instituted in 1895 with satisfactory results.

At the end of a year's working there were 47 subscribers to the electrophone service and in twelve years this number had increased to about 600, and some thirty places of entertainment and churches were available to the subscribers.

Up to the time of the introduction of a form of granular transmitter specially adapted for the purpose of the electrophone service, Blake transmitters and Ader transmitters, the latter similar to those used in Paris, were utilised. Two Ader transmitters were generally used, one in the centre and one near the side of the stage, nearly in line with the footlights. Each transmitter was mounted on a heavy lead base, and was supported on rubber pillars, or suspended by india-rubber bands, from small brackets fixed to the floor, at each end of the transmitter. Either accumulators or Leclanche cells were used to supply the necessary battery power. The induction coil, battery and relay for switching on the current without personal attendance were situated at the theatre.

The theatre lines were terminated in jacks at the exchange, and at the subscriber's end an intermediate switch was provided, in order that the line might be connected at will, either to the ordinary telephone instrument, or to the electrophone apparatus. The latter included a switch consisting of four pairs of jacks, joined up so that two sets of four receivers in series were joined in parallel. The receivers carried a four way cord terminating in a twin metallic circuit plug.

Instructions issued in 1896 on electrophone working included the following :—" The transmitters should not be fitted in close proximity to the bass drum or the trombone of the orchestra."

The increasing popularity of the service soon led to the introduction of improvements in the apparatus used and the methods of switching, and in 1902 the Electrophone Company was reconstructed.

The perfection of the granular transmitter and its adaptation to electrophone working in replacement of the weaker Blake and Ader transmitters offered possibilities of great improvement. The Blake and Ader transmitters were apt to jar and vibrate unpleasantly when subjected to extra loud passages of music, and their performance, although clear and distinct, was generally weak. Numerous standard types of granular transmitters were experimented with, but they were not entirely successful, and a form of granular transmitter, specially designed for electrophone working, was eventually introduced with satisfactory results.

In addition to the regular electrophone service established in London, the transmission of political speeches by eminent

speakers over long distances has on several special occasions been satisfactorily accomplished. A notable achievement was the transmission to London at short notice of a famous speech delivered by Lord Rosebery in Glasgow on September 10th, 1909. It was received in two rooms set apart for the purpose at the office of the *Evening News*, Carmelite House, where reception facilities were afforded for twelve reporters. Within ten minutes of the conclusion copies of the *Evening News* containing the greater portion of Lord Rosebery's speech were being sold in the London streets.

When the first telephone exchanges were established in this country boys were, almost invariably, engaged as operators, although there were some exceptions, and for several years boys continued to be so employed. No doubt boys in their teens found the work not a little irksome, and it is also highly probable that under the early conditions of employment the adventurous and inquisitive spirits of which the average healthy boy of that age is possessed, were not always conducive to the best attention being given to the wants of the telephone subscriber. However that may be, in a few years' time girls began to appear as operators in replacement of the boys and it was soon appreciated that the work of successful telephone operating demanded just that particular dexterity, patience and forbearance possessed by the average woman, in a degree superior to that of the opposite sex. In short, telephone operating proved to be just the sort of work for which girls were admirably fitted.

As the number of operators required to cope with the growing traffic increased, the recruitment of the female operating staff and their selection became a problem of greater importance. Wastage of staff was high, principally due to marriage, and many girls presented themselves for employment as telephone operators who were not in every way suitable. Furthermore, a period of education and practice was necessary before the potential operator became sufficiently well versed and expert in her duties to permit of her being placed in unaided charge of a position at the switchboard. Such tuition as was necessary could not readily be given at the switchboard during working hours without adversely affecting the service. It therefore became desirable to take such steps as would exclude all but those who gave distinct promise of becoming proficient operators, and to provide facilities for training without prejudice to the service.

In London, the number of operators required was large in comparison with that in provincial telephone centres, and the problem of ensuring an adequate supply of proficient operators for the needs of the London telephone service presented peculiar difficulties; steps were therefore taken in August 1899 to recruit and train the needful staff on comprehensive lines, by the establishment of an operating school. This was the first school of its kind in the world. It was first situated at Telephone House, Victoria Embankment, but in 1906 was removed to a suite of rooms specially adapted for the purpose in premises adjoining the London Wall Exchange.

The course of tuition was planned to cover a period of five weeks, and during the last week the operator in training received operating experience at an actual exchange. At the end of five weeks she was usually competent to occupy a telephonist's position at a working exchange.

Similar schools were eventually opened in the larger provincial towns.

The closing scenes of the company's existence, enacted in the court of the Railway and Canal Commissioners, had reference to the purchase price to be paid by the State for the company's plant, land and buildings in London as well as in the rest of the United Kingdom, and are briefly related in Chapter IX.

The author is conscious that the foregoing account of some of the activities of the National Telephone Company in London is inadequate and incomplete. To tell exhaustively, and connectedly, the story of the National Telephone Company in London, more pages than are contained in the whole of this volume would be required. Nevertheless, it is hoped that, read in conjunction with those chapters which relate to technical and other specific phases of telephone development in London, as well as the provinces, enough has been included to enable a comprehensive idea to be formed of the part played by the National Telephone Company from 1889 to 1912 in the administration of the Metropolitan telephone service.

CHAPTER XI

THE MULTIPLE SWITCHBOARD IN VARIOUS FORMS IN THE UNITED KINGDOM, 1890–1912

1. Call wire system. 2. Self-restoring indicator system with upright multiple. 3. Self-restoring indicator system with horizontal multiple. 4. The first metallic circuit multiple switchboard for magneto working. 5. Mixed metallic and earth circuit switchboards with series multiple. 6. Metallic circuit series multiple magneto switchboards. 7. The Post Office N.E. (N) system at Newcastle-on-Tyne, 1889–1906.

THE production of the multiple switchboard in America by the Western Electric Company, its introduction into this country in 1884 and its early development up to about 1890 have been briefly traced in Chapter VII.

Up to the latter date valuable experience had been gained in the practical working of the multiple switchboard in those comparatively few exchanges where it had been introduced and the manipulation of telephone traffic by its means was closely studied by engineers in this country as well as in America. From the outset the principle of the multiple switchboard was voted a success. Numerous patents associated with multiple switching were taken out and therefore the choice of switching mechanism became somewhat involved.

The lively development of the telephone service which continued after the introduction of the multiple switchboard, its varying requirements, the rapid advance in design and arrangement of switchboards and the individual ideas and opinions of the different responsible engineers, all conduced to the adoption of different types of switching devices, of circuit arrangements and of methods of operation; the consequence was that various types of switchboard were evolved and brought into use in different

parts of the country. The time was not yet ripe for the introduction of universal switchboard plant and methods of working. It may be truly said that no two multiple switchboards were in all respects alike in design and arrangement; this was not due solely to the varying requirements and whimsicalities of the telephone using public in different localities, but more particularly to the early obsolescence of switching devices and arrangements which followed from the rapid progress which was made in the technics of telephone switching.

In course of a comparatively short time the existing ideas regarding the fundamental requirements of exchange switching equipment became more or less crystallised, and the National Telephone Company, who in 1893 became responsible for the greater portion of the telephone service of this country, soon attempted as far as was practicable to standardise its practice in regard to the design of switchboards.

The rapid improvements made in switching equipment generally were, however, such as to impose strict limitations upon the possibilities of standardisation, the design of exchange apparatus being in such a constant state of flux at this period that the question of standardisation had to be dealt with very circumspectly; in fact, the progress of telephony throughout its whole history has been accompanied by a constant succession of marked improvements, so that even to-day standardisation of switching methods remains almost a fanciful dream of the telephone engineer.

It is consequently impossible to deal exhaustively in a volume of these dimensions with all the different types of switching plant from time to time introduced, and mention with brief description of some of the prevailing types of multiple switching appliances employed must therefore suffice.

So far as the National Telephone Company was concerned, the methods of working practised for multiple exchanges for some time prior to the introduction of the common battery system were almost confined to the call wire system with branching multiple generally arranged horizontally, and the magneto calling and clearing system with series multiple arranged vertically; the Western Electric Company's self-restoring indicator system with branching multiple was also utilised to a limited extent with both horizontal and vertical multiples. These systems are dealt with

in this chapter, but it is desired to emphasise that the distinct types only are described and that it is not practicable to make reference to all the variations and modifications in design and arrangement of equipment and in circuit arrangement of these types variously employed.

During the earlier part of the period in question the Post Office did not actively engage in the telephone business, except in so far as the trunk line service, to which a separate chapter is devoted, was concerned, but a short description of the novel and original system introduced by Mr. A. W. Heaviside, of that administration, at Newcastle-on-Tyne is included.

1. *Call Wire System and Horizontal Multiple Boards*

The call wire system was at one time freely used in certain parts of the country, more particularly perhaps in Scotland, in Manchester and the Potteries. In the call wire system each subscriber was provided with a direct circuit between his instrument and the exchange through which the desired conversations with his correspondents were passed. This circuit was at one end normally terminated at the subscriber's instrument, and at the exchange was insulated. In addition to this line some 40 to 60 neighbouring subscribers had the joint use of a call wire, by means of which they were enabled to communicate with the operator and give her the necessary instructions regarding the connections they required. This call wire was normally terminated on a switch or call key at the subscriber's instrument, and connected at the exchange to the receiver of an operator who was constantly listening.

By depressing the call key the subscriber was placed in direct communication with the operator to whom he gave his telephone number and the number of the subscriber with whom he desired to speak. After repeating the two numbers, the operator connected the two circuits together by means of a cord or pair of cords; after waiting for this operation to be performed the calling subscriber himself rang the distant subscriber and when conversation terminated he again depressed the call key and requested the operator to clear the connection.

The call wire system possessed the advantage that the switching arrangements at the exchange were of a comparatively simple character, and the use of complex signalling apparatus was

avoided, but it had the disadvantage that a second circuit was required to be led into each subscriber's office and that competition ensued between subscribers in demanding, on the same call wire, the operator's attention and services.

The call wire system was at one time considered to be well adapted for working with switchboards with a horizontal or flat

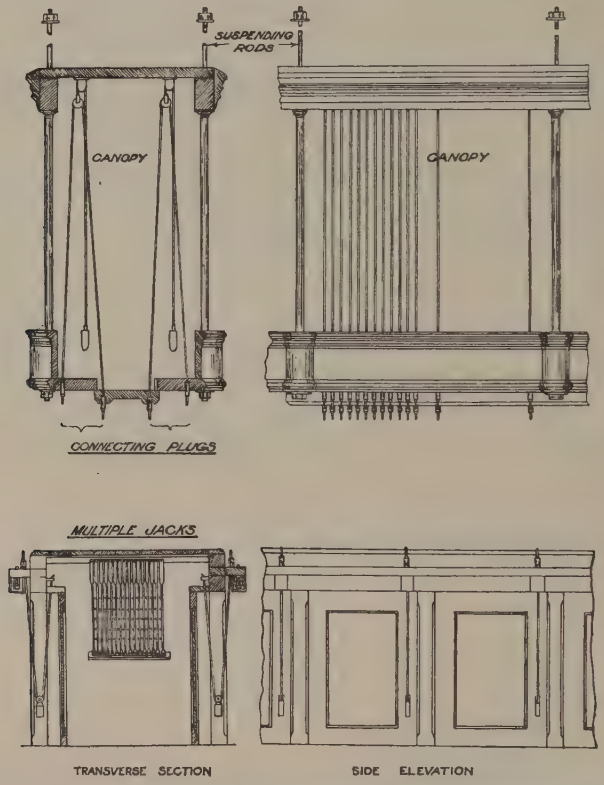

Fig. 85.—Double-cord Call Wire Switchboard with horizontal multiple. Section and part elevation.

multiple. It has been mentioned that the flat multiple originated with Mr. F. B. O. Hawes, of the United Telephone Company, and was first introduced in London at that company's exchanges, Oxford Court and Chancery Lane. The Western Electric Company adhered to the use of a vertical multiple and all their multiple switchboards were so equipped, but in a number of exchanges in this country flat boards were erected and continued

in service for many years. At this time, *i.e.*, before the expiration of the multiple patent, the cost of multiple equipment was considerable and the flat board (reference is not made here to the original flat multiple board of Mr. Hawes) was an attempt to reduce the cost of the expensive multiple equipment by making a given reach of multiple available to double the number of operators, thus halving the multiple equipment necessary to be provided. The so-called flat multiple, which was arranged in a horizontal instead of a vertical plane, in the form of a table, accomplished this object by virtue of the fact that it permitted the employment of operators on both sides of it. To the operators on one side of such a multiple the jack numbering, of course, appeared reversed. With the flat board, a difficulty was presented in providing suitable accommodation for indicators within reach of the operator for restoration by hand, but with the call wire system calling or clearing indicators were not used and therefore this objection did not apply.

Mr. Dane Sinclair, one time engineer-in-chief to the National Telephone Company, was the principal advocate of the horizontal multiple, and in 1889, in association with Mr. H. F. Jackson, he patented the idea. Particulars of the patent are contained in Specification No. 9096, of June 1st, 1889. The specification claimed a horizontal arrangement of jacks in rectangular blocks, so that each jack was common to two operators, one on each side. Provision was made for the calling indicators, cords, etc., to be accommodated along each side of the horizontal board and the arrangement was made applicable to either double or single cord systems.

For exchanges up to 2000 lines where the call wire system had been decided upon, the double cord system was usually fitted. In Fig. 85 a switchboard of this pattern is illustrated. This type of board was at one time in use at several Scotch exchanges. The circuit connections are shown in Fig. 86.

The multiple jacks were joined up to the two line wires; in earth circuit systems, the short spring was used as line wire, the other being earthed at the test jack. There were no local or answering jacks, and in order to place all subscribers well within reach of the operator, the multiple was repeated every five panels. The jacks were 5-point branching jacks. The junction lines were worked on single cords, the lines passing through a screened contact

jack in the centre of the table; thence to translator key, listening key and three way plug. These break jacks were necessary in order to cut off the indicator and keys of one line when two junctions were joined together.

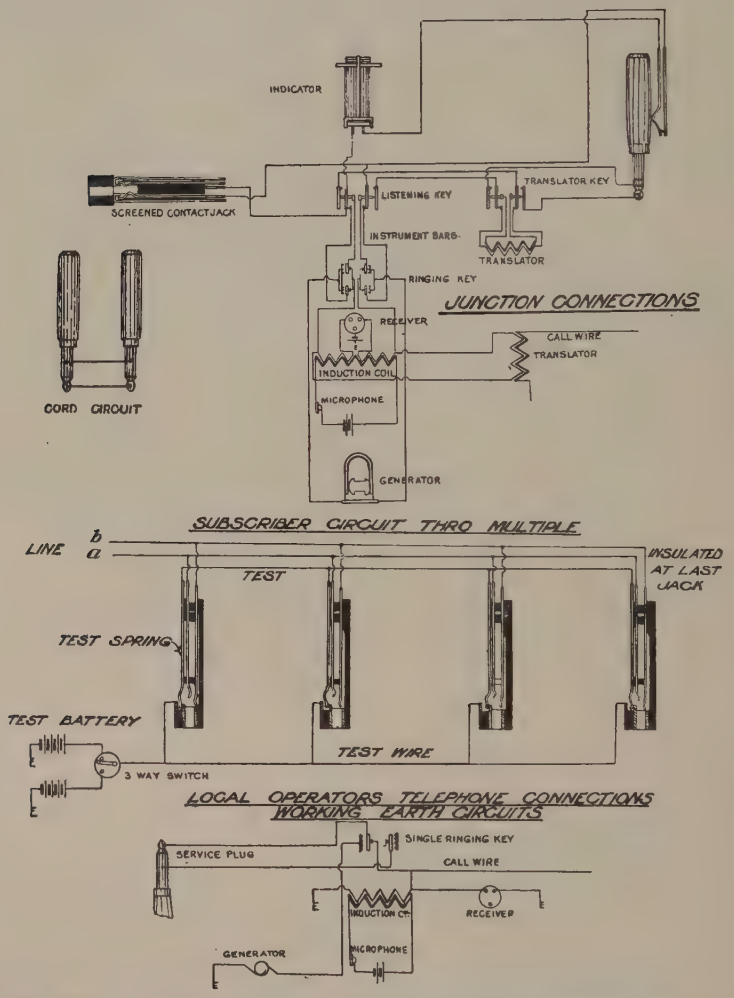

FIG. 86.—Double-cord Call Wire Switchboard with horizontal multiple. Circuit connections.

For large exchanges working on the call wire system single cord boards were usually used. With this system an intermediate cross connecting board or frame was essential, in order that the plugs and jacks should correspond with the subscribers connected

to the respective call wires; unavoidable changes due to removals, etc., were thus provided for.

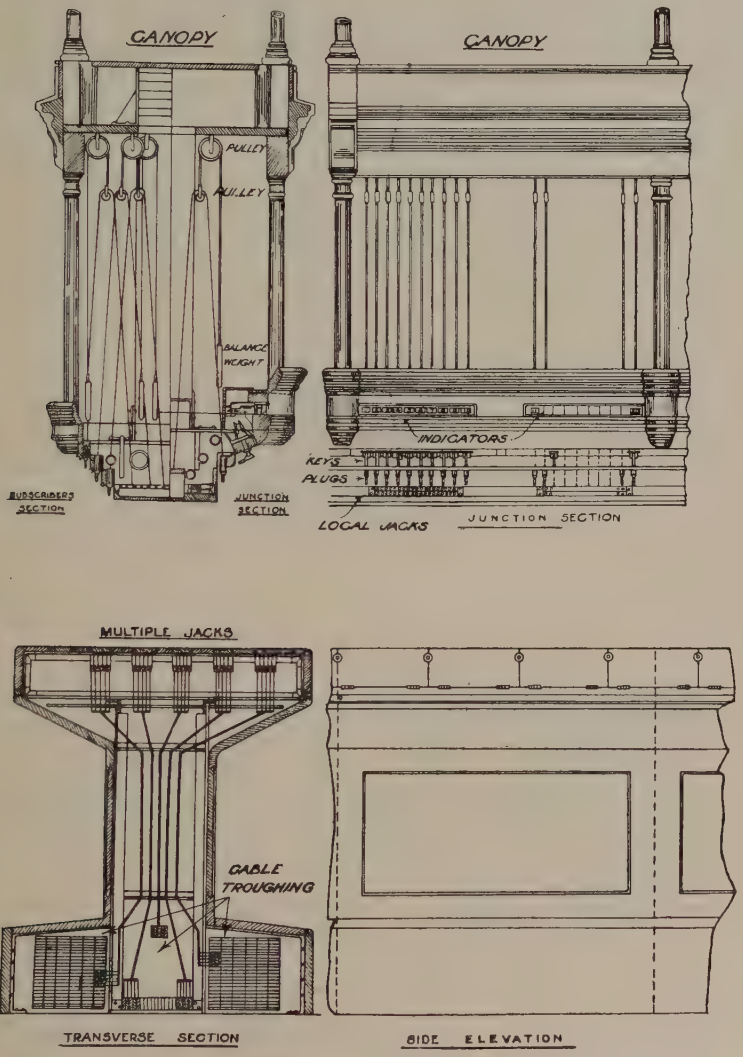

FIG. 87.—Single-cord Call Wire Switchboard with horizontal multiple. Section and part elevation.

In April 1896 a large single cord switchboard with a flat multiple was brought into use at 102 Portland Street, Manchester, with 3200 subscribers' lines working on the call wire system. Fig. 87 gives a section of this switchboard.

Fig. 88 shows the multiple wiring.

Fig. 89 shows the call wire circuit, breakdown circuit and the single cord junction connections.

The total capacity of the Manchester board was for 7200 subscribers and 600 outgoing junctions. Fig. 90 shows the stepping of the inverted plug shelves situated in the suspended canopy, so as to provide accommodation for three rows of plugs. Plugs were fitted only to correspond with the number of subscribers on the respective call wires, these being grouped so as to make up the average number of fifty subscribers per operator.

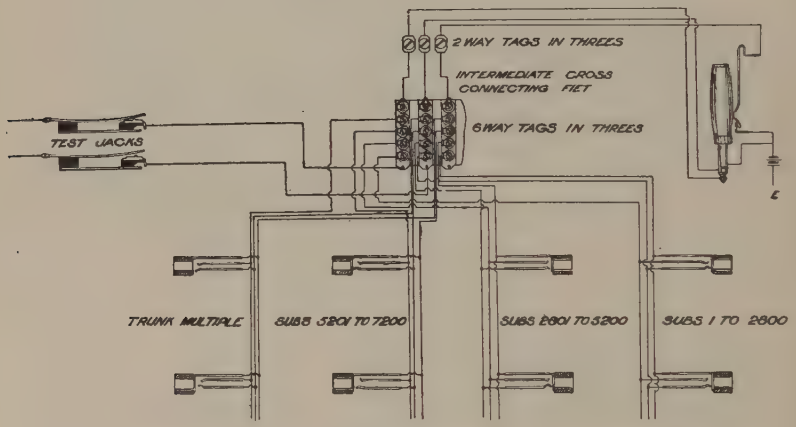

Fig. 88.—Single-cord Call Wire Switchboard with horizontal multiple. Multiple wiring.

On receipt over the call wire of a demand from a subscriber, who, as already stated, gave both his own number and the number of the subscriber with whom he desired to converse, connection was established by insertion of the plug associated with the calling subscriber's circuit into the multiple jack corresponding to the number of the subscriber required. By means of the magneto provided the subscriber originating the call then rang through the exchange to the distant subscriber, without operating any signal or apparatus at the exchange.

The numbering of the 3-point branching jacks was duplicated so that the numbers might be discerned by operators situated on either side of the board. The multiple was arranged with six panels or blocks of 100 in the length of each multiple and accommodated thirteen such panels in the width. Between the jacks

and the edge of the table were placed the single ringing keys and call wire keys for connecting the operator's telephone with call wires to other exchanges in the same area.

The engaged test was made by means of a metallic pin fitted into a vulcanite thimble carried on a finger of the operator's hand.

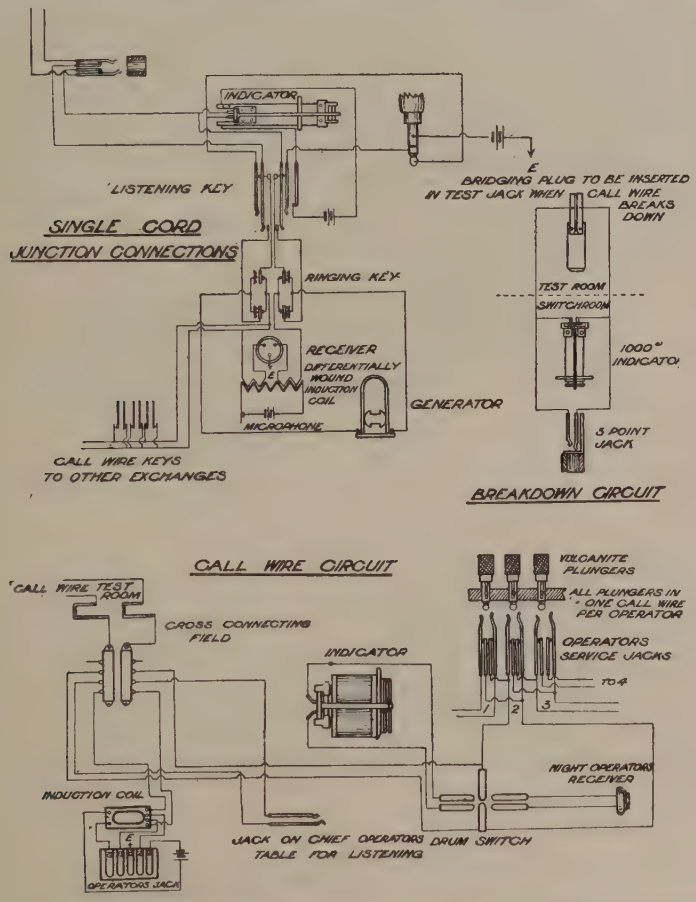

FIG. 89.—Single-cord Call Wire Switchboard with horizontal multiple. Single cord junction connections and call wire circuit.

The test circuit was arranged as shown in Fig. 88. The test wire was brought to the front of the canopy of the board alongside the plug of the relative line, where it was terminated in a small stud; this was done in order to give the operator facilities for testing the line of the calling subscriber to provide against possible cases

of omission on the part of the subscriber to give the clearing order. This provision was necessary in order to obviate triple connections being made. It should be borne in mind that only the " calling " subscriber was able to give the operator the requisite clearing instructions. If, through forgetfulness, or if the call wire was busy, or for other reason he failed to obtain restoration of the circuit after conversation the called subscriber's circuit was still held engaged; if in these circumstances another call was originated it was necessary that the operator should ensure that the previous connection was cleared at its originating position, before establishing the required connection. The engaged test battery was

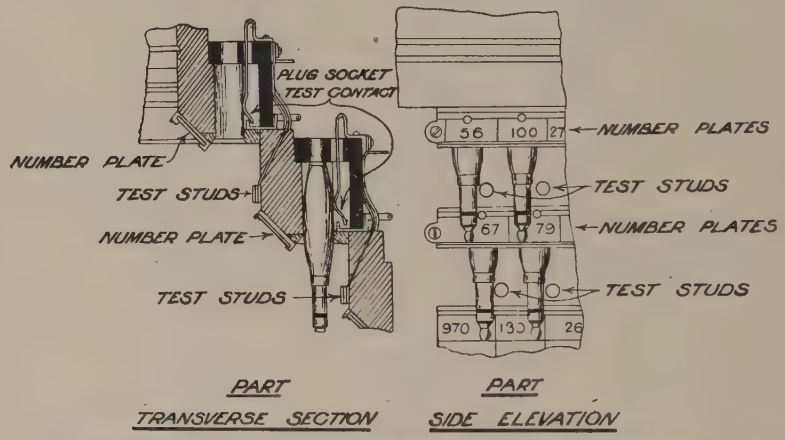

FIG. 90.—Single-cord Call Wire Switchboard with horizontal multiple. Details of plug shelves.

applied to the calling subscriber's circuit immediately on removal of the relative plug from its inverted socket, by means of the spring contact associated with the socket in which the plug normally reposed.

The drawing in Fig. 87 shows on one side the subscriber's section, and on the other side the junction section; the junction lines ended in single cords and plugs as shown in Fig. 89. The junction jacks were fitted immediately beneath the plugs. Junction indicators were of the self-restoring type.

The call wire circuit is shown in Fig. 89. Before being connected to the operator's telephone, the call wires passed through the " call wire board " where switching provision was made for night service, and for grouping call wires according to traffic

requirements. By means of an arrangement of "plunger switches" the call wires could be grouped in various combinations so that they might be distributed according to the number of operators on duty at different periods. A series of "drum switches," each accommodating 24 call wires, was utilised for throwing the call wires on to indicators, for night working. If a call wire became faulty the subscriber was deprived of the ordinary means of communicating with the operator until the fault was rectified. To overcome this difficulty, arrangements were made for the subscriber's direct exchange lines associated with any particular call wire to be connected to 1000 ohm indicators until the fault was cleared, the subscribers affected being asked to call the exchange by ringing until further notice. These indicators were mounted on a "breakdown board" or at a spare section of the multiple board, the former arrangement being preferable for large exchanges. The operator at the breakdown board, after observing an indicator shutter to fall, plugged in to a jack associated with it and, after ascertaining the number required, repeated it to the operator at the position where the faulty call wire was terminated, over a call wire provided for the purpose, and the connection was then completed in the ordinary way.

The author is indebted to Mr. G. S. Wallace, of Manchester, for the photograph showing a portion of the Manchester switchboard in Fig. 91, and to the editor of the *Post Office Electrical Engineer* for permission to reproduce it.

The introduction of incandescent lamps for signalling purposes eventually brought about a revolution in signalling apparatus. Although the incandescent lamp signal has been and still is particularly associated with the common battery system in which lamps are now exclusively used at the exchange for signalling, lamps were actually used for that purpose before the common battery system had been developed to a practical issue. The idea of utilising lamps apparently originated entirely in the United States and appears to have been first seriously mooted in 1893 by Mr. J. J. O'Connell; in 1895, when Mr. C. J. Phillips, at that time assistant engineer-in-chief to the National Telephone Company, paid a visit to America for the purpose of examining the merits of an automatic system devised by Mr. Romaine Callender, he visited New York, Buffalo and Chicago; he was much

impressed with American methods of junction working and brought back with him the idea of employing lamp signals in this country.

It may not be out of place to mention here that automatic signalling, though not by means of lamps, had been employed to a limited extent in this country at a previous date. The British Post Office, in their permanent current system, utilised automatic signals denoted by the movements of the needle of an indicator relay automatically operated as described in Chapter V; in 1891 the second multiple equipment at Liverpool was fitted with automatic clearing signals in the junction circuits; they took the form of galvanometer needles which remained deflected so long as the line was engaged, but returned to normal when the "A" operator cleared.

In spite of its great advantages, signalling by means of lamps did not at once spring into prominence owing chiefly to inability on the part of lamp manufacturers to produce a uniformly satisfactory article, and it was not until the difficulties experienced had been overcome and improvements in manufacture brought about that full advantage could be taken of lamps for signalling purposes. The earliest lamps used were designed to work at voltages of 2 and 4, but with experience the adoption of higher voltages became desirable and the tendency has since been steadily to increase the voltage, with general advantage.

As a result of Mr. C. J. Phillips' report on his return from America, consideration was at once given to the introduction of lamps in this country in replacement of existing methods of signalling, and on his recommendation they were adopted generally by the National Telephone Company, first for junction working. Lamp signals for subscribers' lines followed quickly after.

In 1898, certain arrangements were evolved and patented by Messrs. Sinclair and Aitken, and certain exchanges of the National Telephone Company, previously worked by call wire were modified, principally for the purpose of dispensing with the objectionable call wire and introducing in its place signalling by means of lamps.

The Manchester switchboard, to which allusion has been made, was one of those to be converted from call wire working to lamp signalling. Calling and clearing lamps were fitted in the canopy.

FIG. 91.—Single-cord Call Wire Switchboard with horizontal multiple, Manchester Central Exchange (after conversion to lamp signalling).

(From a photograph loaned by Mr. G. S. Wallace, by permission of the Editor of the Post Office Electrical Engineers' Journal.)

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FIG. 92.—Call Wire Switchboard with horizontal multiple, Glasgow Royal Exchange, 1893.

(*From a photograph loaned by Mr. E. J. Johnson.*)

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The call key associated with the subscribers' instruments for call wire working was retained and utilised by the subscriber to give the necessary calling and clearing signals accomplished by earthing the " b " line. In calling, depression of the key caused a current to flow from a 24 volt battery situated at the exchange through the " b " line and a line relay which lighted the calling lamp; this lamp continued to glow until the insertion of the answering plug, when it was extinguished by the operation of a cut-off relay. The old practice followed by subscribers of ringing through one to another after establishment of the connection by the operator, in vogue during the days of the call wire system, was continued, this being possible without indication being given at the exchange. The clearing signal was also given by depression of the call key. A description and diagram of the system are given in Aitken's " Manual of the Telephone."

The conversion of this board to the ring through lamp call and clear system as described is fairly typical of what transpired at other exchanges similarly worked by call wire when the call wire system was abandoned, the systems adopted differing in minor detail only. Conversion of the call wire exchanges in this country to lamp signalling commenced generally about 1900. Norwich was one of the first towns to be dealt with.

The flat switchboard at 102 Portland Street, Manchester, continued to give service until May 26th, 1917, when the subscribers it accommodated were transferred to new common battery equipment installed for the Post Office in the City Exchange building in York Street.

Another exchange of historic interest, with a flat switchboard, is illustrated in Fig. 92. For the photograph, first published, it is believed, in the *Electrical Review*, the author is indebted to Mr. E. J. J. Johnson, of Glasgow. The exchange was known as " Glasgow Royal." The multiple was flat and was first worked in conjunction with the call wire system, like the Manchester switchboard. It was installed in July 1893, and, although boards of somewhat similar type had been fitted previously at numerous other places it was, at the time, the largest board of the kind brought into use. In September 1901 this switchboard was accorded treatment similar to that of the board at Manchester when call wire working gave way to the ring through lamp call and clear system.

2. Self-restoring Indicator Branching System with Upright Multiple

The self-restoring indicator branching system was another production of the Western Electric Company of America, and was available for commercial service in the year 1892. It was protected in this country by British Patent Specifications Nos. 4428

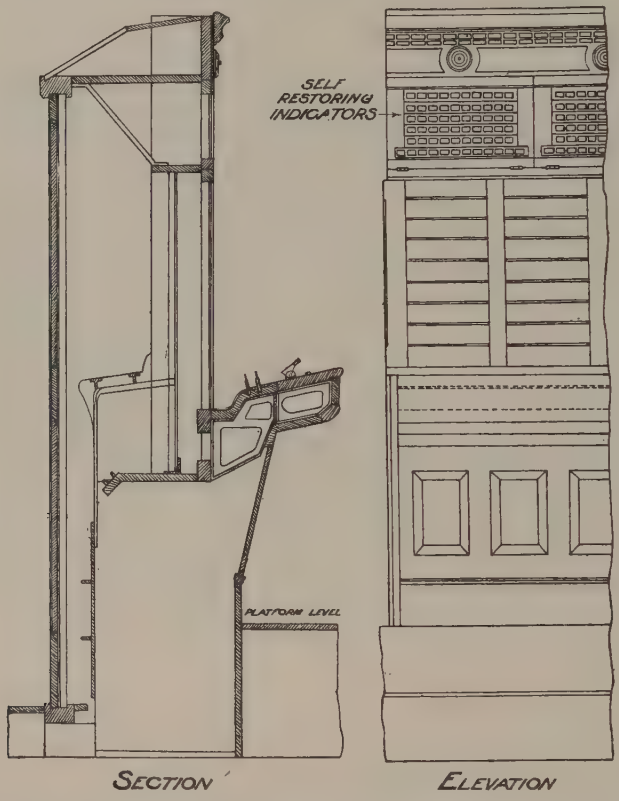

FIG. 93.—Branching-multiple, Self-restoring Indicator System. Section and part elevation of switchboard with upright multiple.

of March 5th, 1892, and 17160 of September 26th, 1892, both in the name of J. E. Kingsbury. It was subsequently utilised in several places in this country and therefore deserves mention.

Several advantages were claimed for the system over the series multiple system. The possibility of faults in the multiple jacks due to dirty contacts was avoided. The operator had no cause to restore by hand the calling and clearing indicators, and the

indicators could, therefore, be placed above her head over the multiple, thus increasing the space available for multiple jacks.

A section and part elevation of an upright board with self-restoring indicators is shown in Fig. 93, and the multiple wiring in Fig. 94. The short inner spring and inner barrel of the jacks were the two lines, and these were multipled throughout the board in the usual way, with a branch to the back coil of the calling indicator. The outer springs were associated with the test circuit. They were of equal length and were joined together on the insertion of the plug by an insulated ring associated with it. The spring connecting with the test wire had a branch connection to the front ring of the jack. The opposite springs were all joined together and had a connection to battery and earth or common

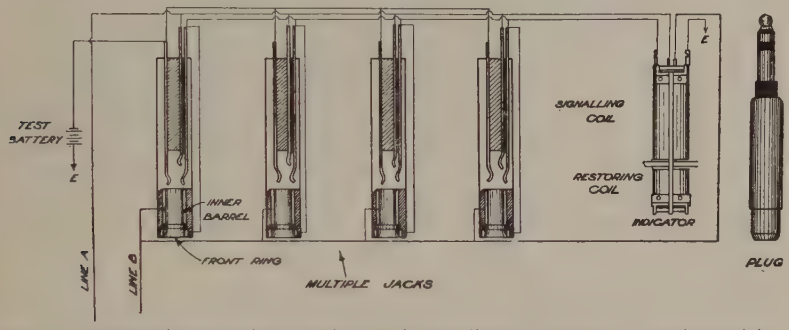

Fig. 94.—Branching-multiple, Self-restoring Indicator System. Multiple wiring.

return. The test wire passed to the corresponding jack on each section in the usual way and had a branch to the front coil of the indicator; the other side of this coil was connected to earth.

The cord circuit connections are shown in Fig. 95. Upon insertion of the answering plug into the jack of the calling subscriber, the two test springs became electrically connected through the insulated ring of the plug; the indicator was thereupon restored, and as the current was maintained so long as the plug remained in the jack, it was also locked against any ringing current on the line. The second line was similarly affected upon insertion of the calling plug. Whilst the operator was listening on the line, the ring off indicator was locked, but when the operator's telephone was thrown out of circuit and the ring off indicator only was shunted across the lines, it was free to respond to any ringing

current. If upon test a line was engaged, part of the restoring current was shunted through the operator's receiver and gave the engaged signal in the usual way.

The first switchboard with upright branching multiple and self-restoring indicators fitted in this country was that of Hull in

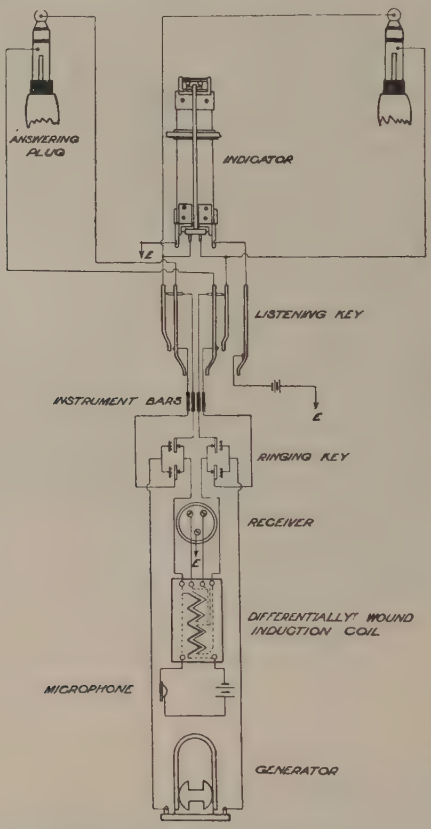

Fig. 95.—Branching-multiple, Self-restoring Indicator System. Cord circuit.

1893. A photograph of this exchange taken immediately before the switchboard was brought into service and kindly supplied by Mr. E. Williamson, of Glasgow, is reproduced in Fig. 96.

As a digression, perhaps the circumstances which led up to the installation of this switchboard may be related here. In Hull, a telephone exchange was provided by the National Telephone Company in the early 'eighties, but as a Post Office licence was

FIG. 96.—Self-restoring Indicator, Branching-multiple Switchboard at the National Telephone Company's Exchange, Hull.

(From a photograph loaned by Mr. E. Williamson.)

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FIG. 97.—Self-restoring Indicator, Branching-multiple Switchboard at the National Telephone Company's Avenue Exchange, London.

(*From a photograph by Mr. Alfred Perkins.*)

FIG. 98.—Rear view of Section of Self-restoring Indicator, Branching-multiple Switchboard at the National Telephone Company's Avenue Exchange, London.

(*From a photograph by Mr. Alfred Perkins.*)

[*To face page* 287.

not forthcoming the plant was recovered and nothing further was done by the company until 1890. Meanwhile, the telephoning of Hull was undertaken by the Post Office and an exchange was opened with the usual Post Office equipment pertaining to that period, already described in Chapter V. A metallic circuit system with permanent current signalling, Gower Bell telephone instruments and line plant comprising gutta percha-insulated cables laid underground, was installed.

By January 1st, 1891, the National Telephone Co., Ltd., had secured a licence and they opened an exchange of non-multiple magneto switchboards of the company's standard pattern as a temporary measure. Meanwhile, the installation of the Western Electric Company's branching multiple self-restoring indicator switchboard previously referred to was put in hand. The whole of the work of installation was carried out by the National Telephone Company's staff, under the direction and superintendence of Mr. E. Williamson.

The Hull Exchange was followed almost immediately by the equipment of the much larger exchange, "Avenue," situated in Lime Street, London, with a switchboard of similar type, opened for service early in August 1894. A view of the switch-room, showing a portion of the new switchboard, from a photograph by Mr. Alfred Perkins, is given in Fig. 97. A rear view of one of the sections, showing the multiple cabling, appears in Fig. 98.

Avenue Exchange continued to give good service until the early part of January 1912, when it was demolished after transfer of the subscribers to a new common battery exchange with ancillary jack equipment provided by the Post Office. The Avenue Exchange of the National Telephone Co., Ltd., was included in the notices of objection served by the Post Office upon the company in 1910, and consistent with the view held by the Post Office that the company's plant comprising the Avenue Exchange was unsuitable to its requirements, the entire plant, exchange, lines and subscriber's apparatus was duplicated.

Another exchange equipped with a self-restoring indicator branching multiple switchboard was that of Belfast, provided in the year 1900. This board was similar to the Hull and Avenue boards, but was equipped for single auto-clearing and auto-ringing controls.

3. *Self-restoring Indicator Branching System with Horizontal Multiple*

The self-restoring indicator branching system was regarded as being peculiarly adapted for working in conjunction with flat switchboards. The spring jacks in this system were joined in parallel, and no trouble was likely to arise from dirty jack contacts; the indicators were of the self-restoring type, and could be placed conveniently in the canopy suspended above the horizontal multiple.

A section and half elevation of a flat switchboard as adapted for working on the branching system with self-restoring indicators are shown in Fig. 99. The particular board illustrated had a capacity of 6000 lines and is typical of a number of boards employed at one time at several London exchanges. The local jacks were on the upright face of the table, immediately above the key shelf, and the answering plugs and listening and ringing keys were on the key shelf. A special key was also fitted on this shelf for connecting the operators' sets together. The calling plugs were overhead, on the under side of the canopy, so that only these cords were over the multiple when connections were made.

The electrical connections were precisely similar to those described for the upright type of branching board with self-restoring indicators. The jack mountings joined end to end so that a flat, table-like surface was formed. The jacks were multipled every six panels as on the upright type of board, but as there were no dividing strips of wood the total length of the multiple (end to end of the board) was somewhat less. The number of jacks required for a flat board was therefore a little more than half that required for an upright board of equal capacity. In the flat board $1\frac{1}{6}$th multiples served eight operators or 400 subscribers, and on the upright, one multiple served four operators or 200 subscribers. The outgoing junction wires were multipled every fifth panel, in the centre of the board, and so were likewise common to the two sets of operators.

Flat boards differing in some essentials from the one described were also used in London; the principal difference was that the outgoing junctions were multipled on the upright over the subscribers' local jacks, so that this multiple was similar to that of an upright board. The multiple jacks were arranged as described for the previously mentioned board, but the "out"

and "in" multiple cables were looped in such a manner as to allow the strip of jacks to be lifted upwards for purposes of

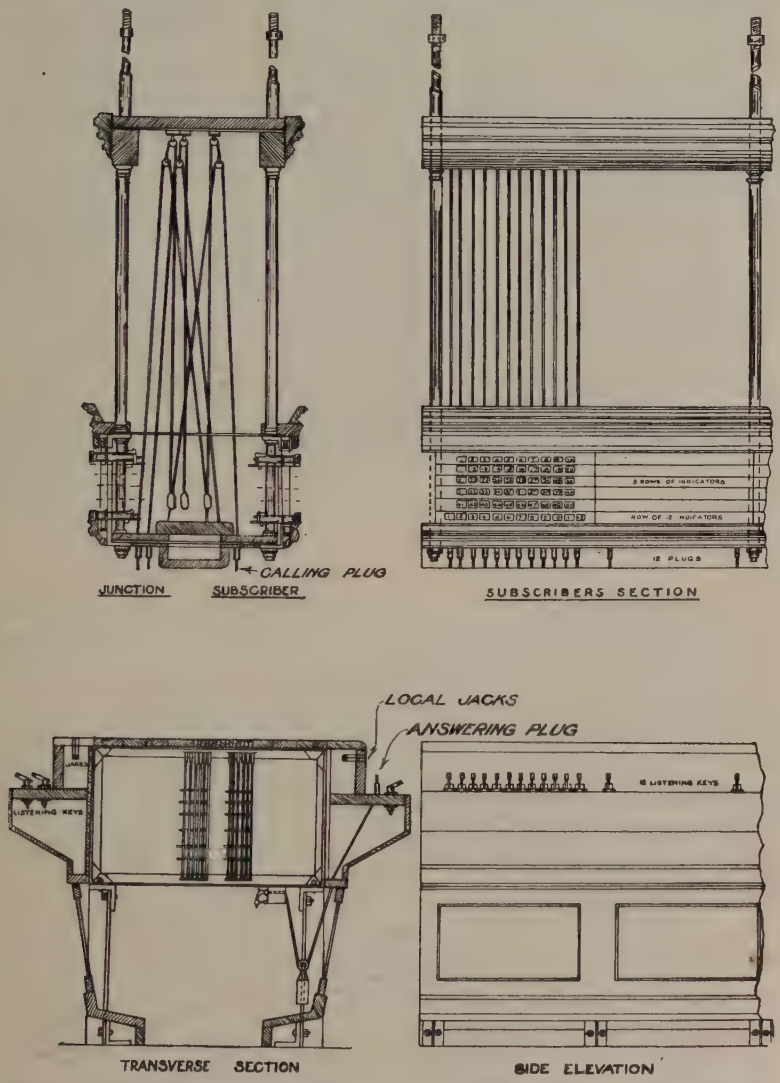

FIG. 99.—Branching-multiple, Self-restoring Indicator System. Section and part elevation of switchboard with flat or horizontal multiple.

inspection and repair. Both plugs were on the key shelf; consequently when a connection was made between two subscribers on the same exchange the cord of the calling plug lay over the

face of the jacks. As, however, this arrangement was only used in exchanges where the percentage of local traffic was low, most of the connections were on the upright, between subscribers' local and outgoing junction jacks, and the number of connections having cords over the multiple were not sufficiently numerous to cause inconvenience.

The London exchanges equipped with self-restoring indicators, in conjunction with a branching multiple, arranged horizontally, were as follow :—

Holborn.	Hop.
Bank.	Gerrard.

Fig. 76 is from a photograph of the Gerrard Exchange during construction, taken by Mr. Alfred Perkins, and Fig. 100 shows that of Bank. The latter, situated at 31 Queen Victoria Street, E.C., is of peculiar interest, first because it is in a sense the relic of the former historic exchange, commonly known as " Queen Vic," and second because the self-restoring board shown in the illustration is the only exchange of its type which remains to give service at the time these words are penned, viz., February 1924.

The author has to thank Mr. G. F. Greenham, of London, for the loan of the photograph from which the latter illustration was prepared.

In spite of the fact that with the flat board economy was effected in the capital cost of multiple equipment, there were other costs and serious disadvantages which attached to switchboards of this type. The cost of cabling was greater than for an upright board. The various parts were particularly difficult of access for maintenance purposes, and repairs could not readily be executed during busy hours of the day without risk of interference with the service. The principal justification for the flat board disappeared upon the expiry of the multiple patent, when the cost of multiple equipment fell, as a consequence of the competition which ensued amongst manufacturers of switchboards.

Particulars of a switchboard with a horizontal multiple of a peculiar type, devised and patented by Mr. A. R. Bennett, and employed by the Mutual Telephone Company, for their exchange in Manchester are given in Chapter IX.

The last flat switchboards to be fitted in the United Kingdom

FIG. 100.—Branching-multiple, Self-restoring Indicator System. Flat switchboard at the National Telephone Company's Bank Exchange, Queen Victoria Street, London, E.C., 1895.

(From a photograph lent by Mr. G. F. Greenham.)

FIG. 101.—One of the last of the Switchboards to be fitted with Horizontal Multiple; the Kinning Park (Call-wire) Exchange of the Glasgow Corporation.

(From a photograph by Mr. E. J. Johnson.)

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were those for the exchanges of the Glasgow Corporation worked in conjunction with the call wire system; they receive mention in Chapter XIV. One of these, namely, Kinning Park, is illustrated in Fig. 101, from a photograph taken by Mr. E. J. Johnson, of Glasgow, immediately prior to its demolition in February 1922.

4. *The first metallic circuit multiple switchboard for magneto working*

An interesting phase in the development of the multiple switchboard was that concerning the transition from earth return to metallic circuit working. Elsewhere in this volume allusion is made to the general adoption by private telephone administrations of line systems which depended upon the earth for the return circuit and to the British Post Office and the Northern District Telephone Company as two of the few exceptions to this practice; also that discarding the idea of utilising the earth as return these two administrations adopted, from the outset, metallic line systems. Newcastle was the chief centre of early activity in telephony both of the Post Office and of the Northern District Company, and therefore the North of England may not inaccurately be regarded as the home of the metallic circuit; many problems in metallic working were first met and disposed of in that locality.

The method adopted for working metallic circuits on the slipper jack type of switchboard first installed at Newcastle-on-Tyne is referred to in Chapter VI. When, however, a multiple switchboard became necessary, other arrangements had to be made and the first magneto metallic circuit multiple switchboard to be employed in this country was, it is believed, that fitted at Newcastle about 1888 by the Northern District Telephone Company.

The multiple board erected at Liverpool in 1884, described and illustrated in Chapter VII, was fitted with jacks of the Warner type; it accommodated earth circuit lines only and was not adaptable for metallic working. The first magneto metallic circuit multiple switchboard at Newcastle possessed certain novel features of interest, and a diagram of the electrical connections of the line circuit, and of the operators' cord circuit, kindly supplied by Mr. C. T. Peacock, now of the Post Office Engineering Department's headquarters staff, who was closely associated with the switchboard in question, is shown in Fig. 102.

The principal features of the board were, that two single circuit multiple jacks for each subscriber's line were provided at each point of access, instead of one metallic circuit jack, as became customary ultimately, and that a twin plug suitable for insertion into the two jacks was associated with each end of the double cord circuit. The first type of twin plug used was one consisting of two single steel pins, or prongs, mounted rigidly together in an ebonite block at a distance apart, centre to centre, equal to the jack spacing, so as to admit of its insertion into the "a" and "b" jacks of any subscriber's line. When a plug of this type was inserted into a twin jack, connection was established between

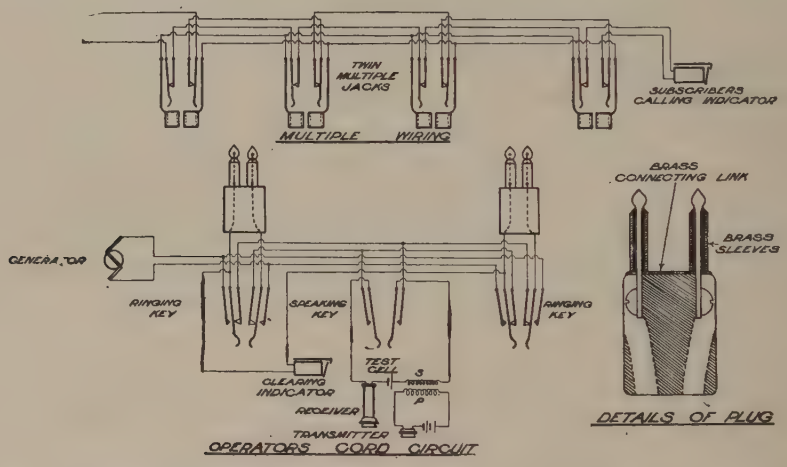

FIG. 102.—Multiple Wiring and Operator's Cord Circuit Connections of metallic-circuit, twin-jack multiple switchboard, Newcastle-on-Tyne, 1888.

the two line wires and the pins of the plug; at the same time the two lines were connected to the two jack bushes, and by means of the common wiring to all the bushes of the same line. A single cell was included in the operator's secondary circuit, and upon tapping, at any position, the two bushes of the jacks of an engaged line, with the two tips of a twin plug, a circuit was completed from the test cell, through the common bush wiring, subscribers' lines and instruments, and operator's receiver; the resultant test click was evidence that the line was engaged.

At a later date, when the board was extended, a modified form of plug, shown in detail in the diagram, was introduced; it had the desirable effect of entirely separating the engaged test circuit

from the subscriber's line and confined it to the bush wiring of the switchboard. This was accomplished by providing the modified form of plug with two brass sleeves, one around and insulated from each pin, and joined together by a strip of brass. On the insertion of a twin plug into a pair of jacks, the brass sleeves of the plug made contact with the respective bushes of the jacks, which were electrically coupled together by the brass strip. If at any other part of the switchboard the test was applied by tapping the two tips of a similar plug against the bushes of the twin jack of an engaged line, the circuit was completed through the operator's receiver, and the engaged test signal was given.

In the diagram the ring off indicators of the twin coil type are shown connected in shunt, but it is understood that, in the first case, they were of low resistance, and joined in series, the two coils being inserted in the circuit in such a way as to maintain a balanced condition. Cross talk trouble was experienced with these indicators until they were fitted with iron shields. The cells associated with the operator's circuit were of the gravity type, and no means appear to have been provided for disconnecting them when not in use.

The disadvantages accompanying the use of the twin jack and plug for metallic circuit working will be apparent.

The first metallic circuit multiple switchboards installed by the National Telephone Company, in which both wires of the metallic circuit were connected on the same jack and single metallic circuit plugs were used, were those fitted at Liverpool and Sheffield in 1893.

5. *Mixed Metallic and Earth Circuit Switchboards with Series Multiple*

The work undertaken by the National Telephone Company in the return circuiting of the existing single lines which preponderated throughout the country is referred to in Chapter IX. The work was of some magnitude, and the process of conversion was of necessity a gradual one and extended over a number of years, even so far as one exchange area was concerned. It was obviously essential that, during the period of transition from earth circuit to metallic circuit working, the switching arrangements should provide for the simultaneous working of both metallic and single lines on the same switchboard, and for the

satisfactory connection of one single line with another, a single line and a metallic circuit, and one metallic circuit with another. It was also necessary that conversions from single to metallic circuit should be readily effected in conjunction with the line work, and that the minimum amount of alteration to exchange apparatus and disturbance to the service should be occasioned.

Fig. 103 shows the multiple connections of a switchboard employed for the accommodation of mixed metallic and earth circuit lines, and Fig. 104 gives the connections of the operator's cord circuit. The principal feature of the system was the use of the 3-point jack for working metallic and single lines together, the multiple test wire being made to serve as return for a metallic circuit. The subscribers' lines were passed first through the

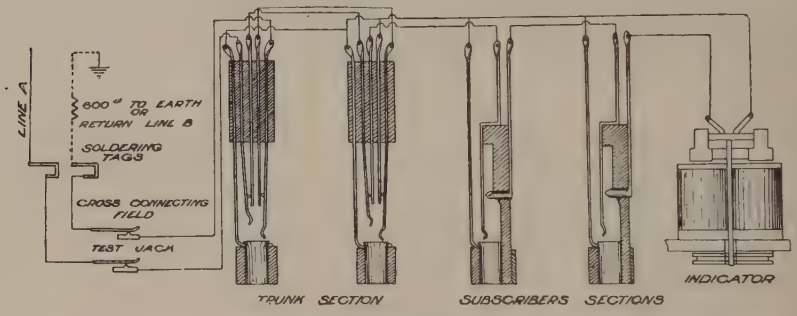

FIG. 103.—Mixed Circuit Switchboard; multiple wiring with 5- and 3-point jacks.

multiple jacks of the trunk sections, and then through the multiple of the subscribers' sections, as shown. Five-point jacks were employed in the trunk and 3-point jacks in the subscribers' sections. The multiple was a series multiple and insertion of a plug into a 5-point jack on one of the trunk sections disconnected all that part of the circuit which lay beyond it on the indicator side. When a connection was made on a subscriber's section, both line indicators were left tagged on to the circuit. During the time a line was working with an earth return, the earth connection at the exchange was made through a 500 ohm resistance coil, mounted on the arrester side of the test board. When metallic circuited, the return wire was connected in place of the earth connection, and the resistance coil recovered.

The retardation coil shown in the cord circuit diagram, connected in series with the test battery, between the sleeve conductor

and earth, was of high self-inductance; it was introduced to minimise the detrimental effect of the earth connection on a metallic circuit during conversation and, as it was in circuit the whole time the answering plug remained in the jack of a subscriber's earthed line, it also served the purpose of preventing the battery from being unduly drawn upon.

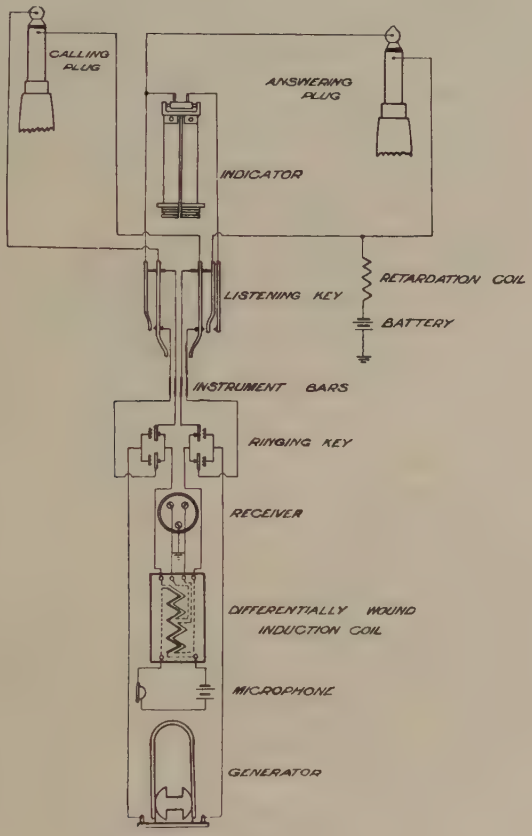

FIG. 104.—Mixed Circuit Switchboard with 5- and 3-point jacks. Operator's cord circuit.

Upon the answering plug being inserted into the local jack, in order to answer a call, the calling subscriber's line was engaged by the test battery simultaneously joined to the test circuit. On an earth circuit line, the circuit was completed by the earth connection at the arresters of the test board. In the case of a metallic circuit, the test current passed through the subscriber's

line and instrument back to the tip of the answering plug, and the insertion in the line circuit of a one microfarad condenser (not shown in the diagram), between the tip of the answering plug and the operator's receiver, was to obviate the false test click otherwise received when the tip of the calling plug was brought into contact

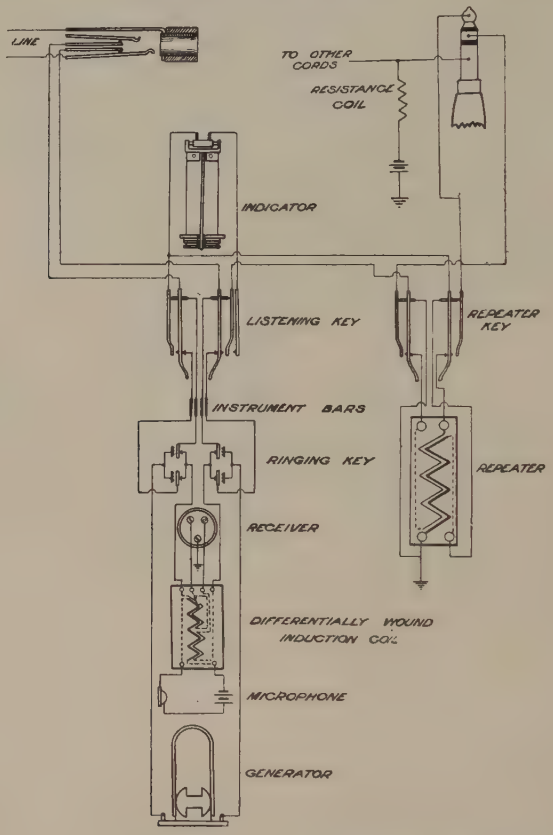

FIG. 105.—Single-cord Junction Connections with repeater.

with the bush of any subscriber's earthed line. So far as the test current was concerned the continuity of the circuit was thus broken by the condenser, which, however, offered no bar to ringing and speaking currents. Three way cords were used on the junction sections, and as the test circuit there was independent of the lines a condenser was not necessary.

Single cord junction connections with a repeater are shown in Fig. 105.

Prior to the adoption of single cord junction working, the entanglement of cords on a busy junction position, equipped with from 20 to 24 double cords, as was usual, was an objectionable feature. The introduction of single cord junction working overcame, in a large measure, this congestion of cords.

Another method employed for the purpose of permitting satisfactory intercommunication between metallic and earth circuits, terminating on the same switchboard, depended upon the use of a translator or repeater fitted in each cord circuit; when connection was required between a metallic and an earth circuit line, its coils were brought into circuit by means of a special key. With the key in one position the answering and calling plugs were in direct connection one with another, and in the other position, the two coils of the translator, one of which was earthed, were brought into circuit. The usual listening key was provided in addition to the special translator key.

It was necessary that the operator should be able to judge whether or not the translator should be utilised in establishing a connection, and therefore it was customary to distinguish the jacks of the metallic circuit lines by encircling them with a white ring.

The two arrangements described for connecting earthed and metallic lines together worked quite satisfactorily during the period of transition from the earthed to the metallic circuit system, but left much to be desired when the work was complete; the cord circuits were then more complicated than was essential or desirable, and included unnecessary apparatus; eventually therefore it became customary to instal simple metallic circuit boards without any special arrangements for connecting earth circuit to metallic lines. When the two classes of line were accommodated on these boards, the " a " wire of the metallic circuit was used for a single line and the " b " wire was earthed on the test board. The objection to this arrangement was that when a metallic circuit was connected through to a single circuit, the benefit to the subscriber whose circuit was metallic was lost, except in so far as the return wire acted as a screen. When two earth circuit lines were connected together, the earth connections were at the subscribers' instruments, and the ring off indicator had one side connected to the lines, the other to earth at the test jacks,

Early practice in junction working was not dissimilar from that employed for subscribers' service, double cords and plugs being generally used. For switchboards on which metallic and earth circuits were worked together, it was at one time customary to provide two jacks per junction line, with a translator connected

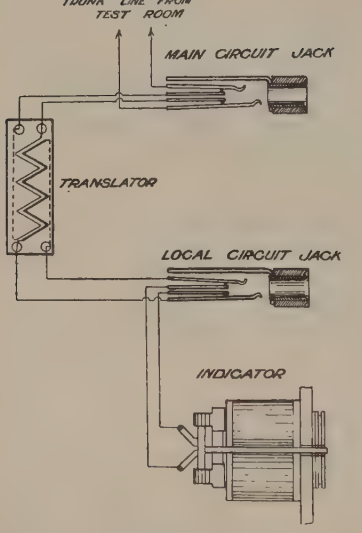

Fig. 106.—Junction Connections on mixed circuit board.

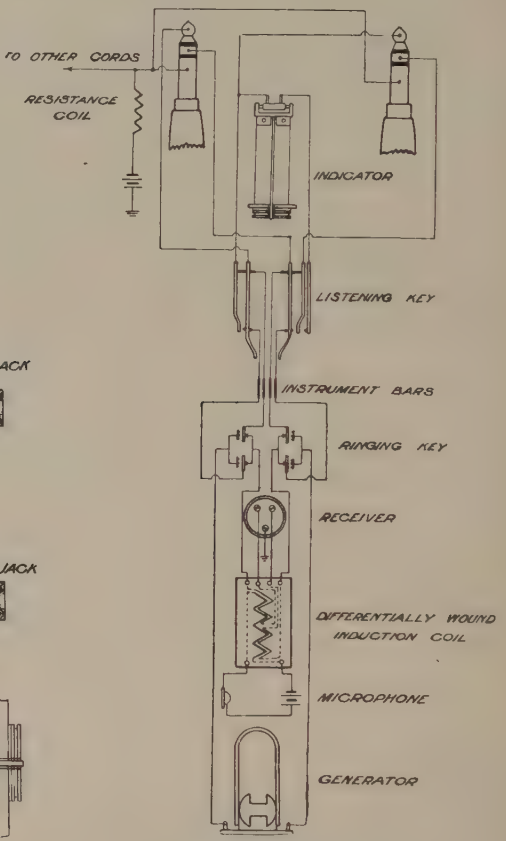

Fig. 107.—Double-cord Circuit for metallic circuits.

between them as shown in Fig. 106. Double cords to the number of twenty per operator's position were commonly provided, the cord circuit being in accordance with Fig. 107. In many places two sets of cords were used, one set for joining metallic circuit to earth circuit, or earth circuit to earth circuit lines, and another set for connecting metallic circuit to metallic circuit lines, and also two sets of jacks The double cord circuit was eventually

dispensed with for junction working at mixed circuit exchanges and the single cord circuit with a combined listening and translator key in each line, as shown in Fig. 105, was adopted in its place. The junction cord connections for exchanges accommodating metallic circuits exclusively are shown in Fig. 108.

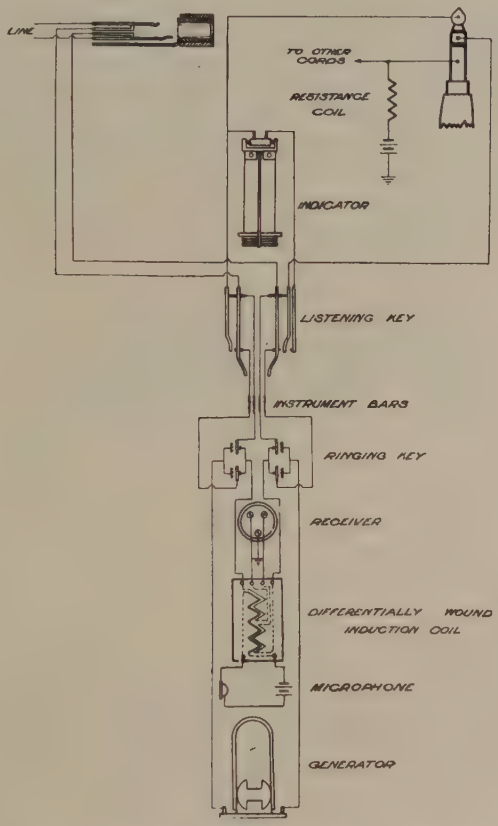

Fig. 108.—Junction Cord Connections for metallic circuit switchboards.

In early call wire junction working clearing signals were not provided in the junction circuits and the operator at the originating exchange gave the order to clear to the operator at the distant exchange over the call wire. At the outgoing end call wires were normally insulated, but were multipled so as to be available to a number of operators; the distant or incoming end was connected to the receiver of the incoming junction operator.

6. *Metallic Circuit Series Multiple Boards as employed by the National Telephone Company*

In series multiple boards there were two well known methods by which provision might be made for the application of the engaged test, first by the use of 7-point jacks, associated with two way cords and plugs, and second by 5-point jacks in combination with three way cords and plugs, and for some time there existed considerable difference of opinion as to which method was preferable. On the one hand, it was held that the jack, being difficult of access for maintenance purposes, should possess the least possible complications, and, on the other, that the flexible cord, being the part subjected to most wear and tear, and constituting

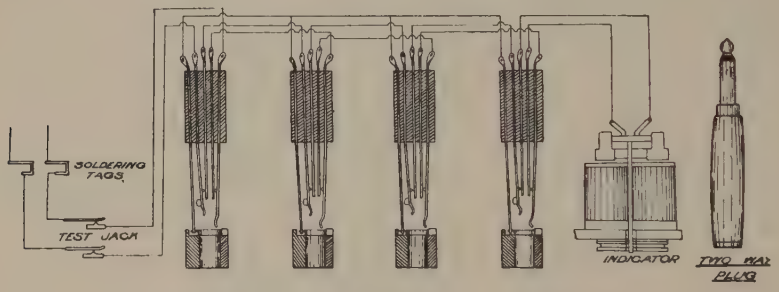

Fig. 109.—Multiple Connections with 7-point break jacks.

the principal and heaviest item of expenditure in maintenance, should also be free from all unessential parts and avoidable complexities. In course of time, however, the objection to the three way cord was largely overcome by improvements in design and manufacture, and consequently the 5-point jack and three way cord gained the day, the 7-point jack being gradually superseded in favour of the 5-point. Experience with the 7-point jack has since demonstrated the superiority of the 5-point jack, in combination with three way plugs and cords.

The 7-point break jack multiple connections are shown in Fig. 109, and the 5-point in Fig. 110; it will be seen that the chief constructional difference is that the 7-point jack is provided with an additional spring to which the multiple test circuit is connected. This spring normally rests against the insulated brass barrel or bush of the jack, but when a plug is inserted, the spring is forced away from the bush of the jack and makes contact with a brass

connection strip, common to all the jacks in the mounting, and connected to earth through the test battery.

The principal circuit difference in the use of 7-point jacks and 5-point jacks, with an additional conductor in the cord and plug, was that in the former case the test battery circuit was included with the jack and in the latter the test battery was connected to the third conductor of the plug and cord. With the 7-point jack the test battery was applied to the barrels or bushes of the multiple jacks through the medium of the extra spring as explained; with the 5-point jack the test battery was connected to the bush of the jack through the sleeve of the plug, from whence it was communicated to the bushes of all the other multiple jacks bearing the same number through the test wire.

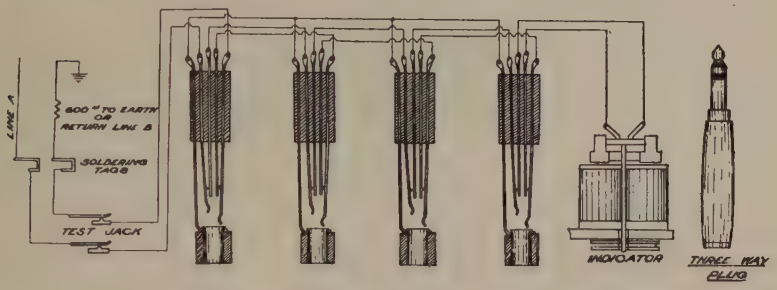

Fig. 110.—Multiple Connections with 5-point break jacks.

In Fig. 111 is given, in the form of a transverse section and front elevation the general design of a 200 line section of a metallic circuit multiple switchboard with series jacks, at one time employed by the National Telephone Company in various parts of the country for magneto working. Each section was 6 feet 6 inches long, and the height was proportioned according to the multiple capacity. The smallest size was 5 feet 3 inches high with a capacity in the multiple panels for 2400 subscribers; the standard size accommodated 3000 subscribers.

Where it was anticipated that the subscribers to be accommodated would ultimately exceed 1200 in number provision was made in the depth, from back to front of the section, for the accommodation of twelve (63 wire) switchboard cables on each cable pin. Smaller boards accommodated only six cables abreast, and consequently could be made about 6 inches less in depth. The section illustrated is of the larger type. Switchboard cable

containing 42 wires was employed between the test board and the first switch section, and 63 wire throughout the multiple, ending at the local jacks.

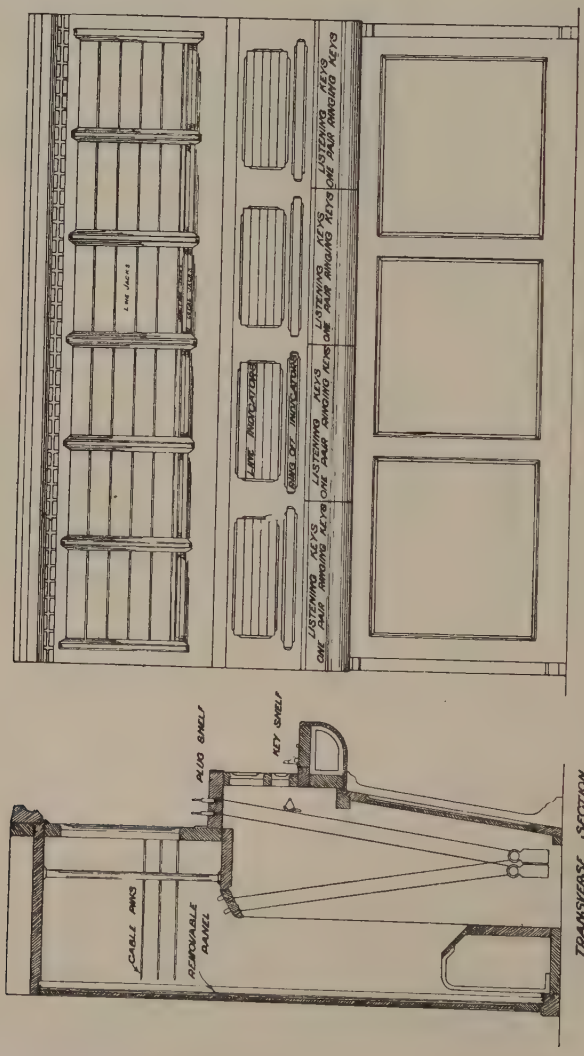

Fig. 111.—Transverse Section and Elevation of 200-line metallic circuit series multiple switchboard.

Each section was designed for four operators' positions, but where traffic considerations permitted three positions only were arranged for. Each operator's position on subscribers' sections originally accommodated 50 subscribers' indicators in five rows of ten, ten pairs of plugs and cords with ring off indicators, listening

keys, and one pair of ringing keys. Five-point break jacks were usually employed; the multiple line connections were as indicated in Fig. 110.

An illustration of a section of a 4-position series multiple switchboard, fitted at Newcastle-on-Tyne, which will suitably serve as an example, appears in Fig. 112. The first sections of this switchboard were originally brought into service when the exchange at 160 Pilgrim Street, Newcastle-on-Tyne, was opened on March 1st, 1896. Each section was designed to accommodate four operators, as in the case of other similar switchboards of this period. Each position originally accommodated 50 subscribers' indicators, in five rows of ten, and 12 pairs of plugs and cords, with their associated ring off indicators, listening and ringing keys.

Experience ultimately demonstrated that the 4-position section, which was 6 feet 6 inches in length, possessed disadvantages of consequence. It was difficult for an operator to complete every connection, especially with a high multiple, without disturbing her neighbour, and sometimes the assistance of the adjacent operator was requisitioned to complete calls upon remote parts of the multiple. Moreover, it was found that the 50 indicators allotted per position was not a satisfactory or economical arrangement, the calling rate being generally such that many operators were able to take greater individual loads. Consequently, the Newcastle board was subjected to certain modifications. The provision of distributing facilities, by the installation of an intermediate distributing frame, permitted the number of indicators per position to be increased, by the addition of two additional strips of 10 indicators each, thus increasing the capacity of each section from 200 to 280, and later on each section was converted from a 4 to a 3-position section.

Incidentally, it may be here mentioned that the Newcastle switchboard continued to be worked on the lines stated until conditions arising out of the Great War, 1914–1918, gave rise to a shortage of capacity, not readily provided for by further extension, and an increase in the calling rate demanded that relief be afforded in the most expeditious manner. This was accomplished by reverting to the original arrangement of four operators per position, which reduced the number of subscribers' indicators and local jacks per position to 70.

Newcastle-on-Tyne was favoured in being served by a metallic return system from the outset, and therefore it was not necessary to make arrangements for working single and loop circuits together on the same board.

The switchboard alluded to was the first metallic circuit multiple switchboard of its type to be fitted in this country. It was supplied by the Western Electric Company, and installed by the engineering staff of the National Telephone Company.

The alterations made to it are fairly typical of the modifications made to other boards of similar original design installed in various parts of the United Kingdom at about the same time.

The 4-position section suffering from the disabilities which have been recounted in association with the switchboard at Newcastle-on-Tyne, the policy was changed and a modified switch section was designed by engineers of the National Telephone Company and adopted as standard for magneto working at multiple exchanges by that company. Its general design is indicated by Fig. 113. Each section measured 5 feet 6 inches in length, instead of 6 feet 6 inches, and comprised five multiple panels instead of six, and three operators' positions in place of four. Instead of the cords and plugs being situated above, and the listening keys below, the indicator panels, the listening keys were brought up to the level of and fitted in front of the plugs, of which there were 14 pairs, so that the two might more readily be identified one with the other.

Provision was made on the bevel of the plug shelf for visual ring off signals, but usually ordinary ring off indicators were fitted below the subscribers' indicators; a horizontal guard rail was provided in front of the indicator panels to prevent the shutters being accidentally released. The indicators were in strips of fifteen, instead of ten as formerly, of which seven strips in all might be fitted, making 105 subscribers' indicators per position.

In order to permit of distribution of the subscribers' circuits over the several operators' positions in conformity with the traffic load, in exchanges where for any reason an intermediate distributing frame was not included, facilities for effecting the necessary cross connections as desired were provided, in the form of small frames, bearing soldering tags on either side, fitted at the rear of the sections as shown in Fig. 113. There were three frames per section, one for each operator's position; to the tags

on one side of each frame the whole of the 105 subscribers' indicators and local jacks accommodated on that position were wired, and on the other side the relative multiple cables were terminated.

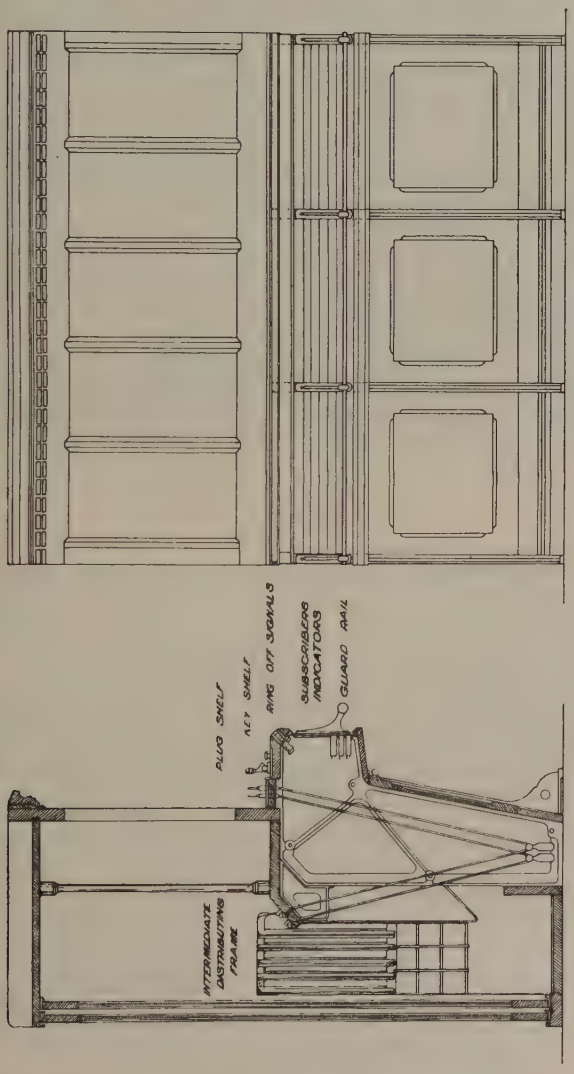

Fig. 113.—Transverse Section and Elevation of 3-position, 5-panel, series multiple switchboard, Birmingham broad type.

The Birmingham Central Exchange, at one time accommodating upwards of 5000 subscribers' lines, and illustrated in Fig. 114, was the largest exchange employing this type of board, which became known as the Birmingham Broad Type.

The introduction and subsequent adoption of the common battery system stopped any further advances of material consequence in the magneto system of working, and the switchboard latterly described may therefore be regarded as the last development in series multiple magneto switchboards.

7. *The Post Office N.E. (N) System at Newcastle-on-Tyne*

In the earlier days of telephony in this country the policy adopted by the Post Office did not provide for active competition with the private telephone administrations, but in Newcastle-on-Tyne, Cardiff and Hull exceptions were made, mainly, it is believed, in the first-mentioned place, through the instrumentality of the late Mr. A. W. Heaviside, one time Superintending Engineer of the Post Office Northern Engineering District. Mr. Heaviside introduced, in Newcastle-on-Tyne, a system in many ways unique and which possessed several features of interest, designed by himself and his staff, chief among whom figured Messrs. W. R. Smith and G. W. Waggot.

The system was generally known as the N.E. (N), or North East (Northern) system. From the outset, as with other Post Office systems, metallic circuits were used. The principal advantages claimed were those of immunity from inductive overhearing, secrecy, *i.e.*, the method of switching did not necessitate or even normally permit of the operator overhearing conversations between subscribers, and triple connnections were impossible.

Unlike other systems, excepting the Post Office universal system, signalling depended upon a permanent current maintained over each subscriber's circuit by means of a battery situated at the subscriber's premises. In the N.E. (N) system a permanent current circulated over each line both normally and when in use, in the Post Office universal system only when the circuit was inoperative. Due to the permanent current, the lines were continuously under an observation test and certain faults were therefore automatically indicated. Daniell cells were used initially for both signalling and speaking, but these were subsequently replaced by Leclanche batteries. The subscribers' telephone instruments were originally of the Gower Bell type, modified later by substitution of Bell receivers for the original Gower receiver with ear tubes.

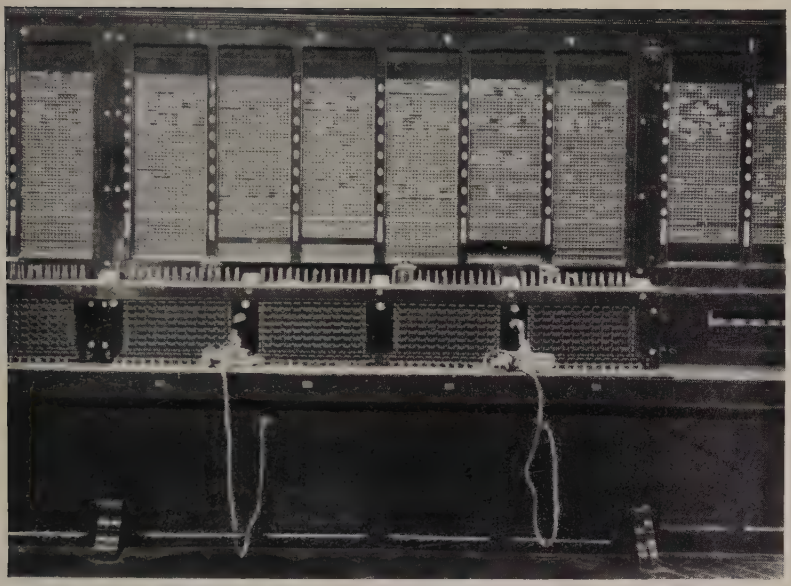

FIG. 112.—Four-position, 6-panel, Series-multiple Switchboard, Newcastle-on-Tyne.

(From a photograph by the author.)

FIG. 114.—Birmingham Central Exchange, 1908.

(From a photograph.)

[*To face page* 306.

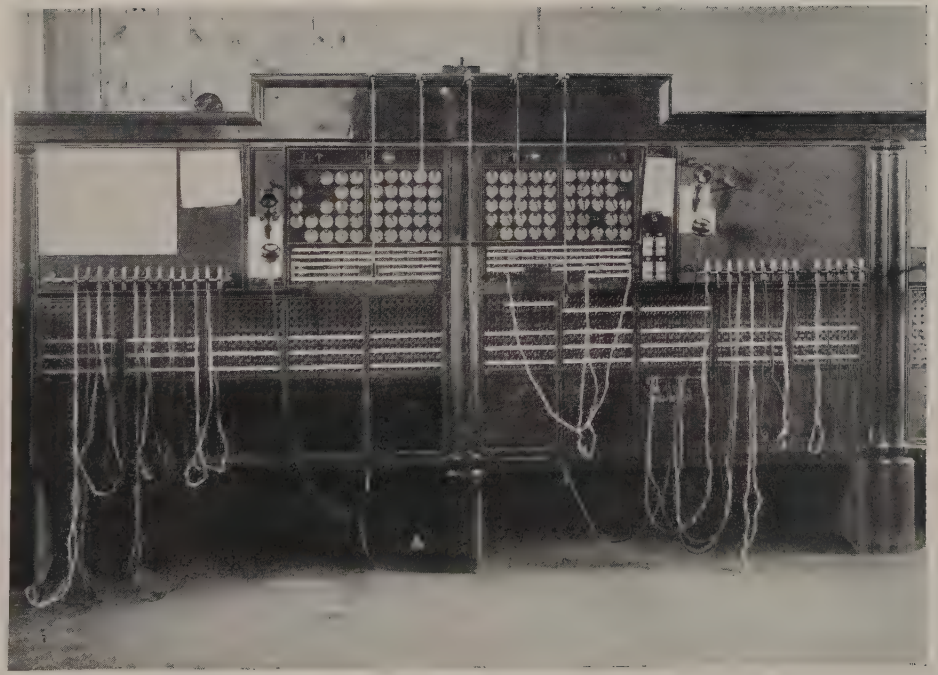

FIG. 115.—General View of No. 1 Section, N.E. (N.) Switchboard, Newcastle-on-Tyne.

(From a photograph supplied by Mr. G. E. Gilpin.)

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A combined indicator-relay with a non-polarised armature was associated with each subscriber's circuit at the exchange, and was used for calling and clearing purposes, the signals being given by means of a polarised needle hung vertically. With the subscriber's telephone in its normal state of disuse, the circulating current deflected the indicator needle to the right and maintained it in that position so long as the conditions remained unchanged. On the subscriber lifting his left hand receiver, the secondary circuit of the induction coil was joined up to line and, by the same movement, the permanent current was interrupted and the non-polarised indicator at the exchange was de-energised, thus closing the night alarm circuit on its armature and allowing the needle to fall into the vertical position. This constituted the calling signal. When the operator answered, the subscriber lifted the right hand tube of his receiver, which closed the local microphone circuit, and joined the permanent current battery to line in a reversed direction. The indicator needle was then deflected to the left and the night alarm circuit broken, thus giving the engaged signal at the exchange.

An illustration showing the general arrangement of one local or subscriber's section of the switchboard is given in Fig. 115.

The signals, communicated as described by deflection of a needle associated with the indicator, did not involve manual restoration of any part of the apparatus after receipt of a signal. The indicators could therefore be mounted on the upper portion of the section, and were enclosed behind a dustproof glass cover; accommodation was provided for two sets of 50, and each section therefore accommodated 100 subscribers in all. The answering jacks were arranged immediately below and in the same relative order as the indicators with which they were associated, and the multiple jacks were accommodated in the lower portion of the section.

Multiple jacks were provided at each section only for those subscribers whose answering jacks were situated at other sections, calls between subscribers whose answering jacks were on the same section being dealt with by calling at the answering jacks. The illustration is of Section No. 1, which accommodated subscribers numbered from 1 to 100; these numbers did not appear in the multiple field. The answering jacks were all arranged in subscribers' numerical order.

The circuit of the operators' answering equipment was extraordinary and complex in character. The operating instrument was connected with a device of special design termed a " multiple detector and call switch," fitted above the subscribers' indicators, by means of a five way flexible cord. A second five way flexible cord, connected to the detector and call switch, terminated in a five way peg of peculiar design for answering and calling.

Fig. 116 gives the connections of one of the operators' sets, with detector and call switch, two of which were normally associated with each subscriber's section of the switchboard, and a third provided as an auxiliary. The detector and call switches were not fitted when the switchboard was first installed, but were subsequently provided in order to simplify the detecting and calling operation. Originally a detector associated with a separate peg was supplied and, as a preliminary to calling a subscriber with the operator's peg, the detector peg was inserted in the spring jack of the number wanted in order to ascertain if the subscriber was at liberty.

The multiple wiring is shown in Fig. 116, together with the special five way peg. It will be seen that a third connection was provided in the multiple wiring, and this constituted a novel and distinctive feature of the N.E. (N) system in that it prevented triple connections from being made. If the connection be traced, it will be found that the insertion of pegs in two multiple positions of the same subscriber's circuit short-circuited the subscriber's lines.

The process of operating a call was briefly as follows :—

(*a*) Receipt of a call was indicated by the needle of the subscriber's indicator assuming a vertical position, due to the permanent current which maintained the deflection of the needle to the right being interrupted at the subscriber's switch-hook, by removal of the left hand tube of the receiver.

(*b*) The operator answered by inserting into the answering jack associated with the calling subscriber's indicator the five way peg connected by flexible cord with the detector and call switch. The needle of the subscriber's indicator deflected to the left when the subscriber removed his right hand tube after hearing the operator answer.

(*c*) Simultaneously with the insertion of the answering peg with the right hand, the operator momentarily depressed with

her left hand the key situated on her handset. This movement closed the circuit of the detector and call switch magnet coils, drew up the armature and made the several contacts contained in the switch. Upon release of the key the armature was retained by current from the calling battery through one of the contacts

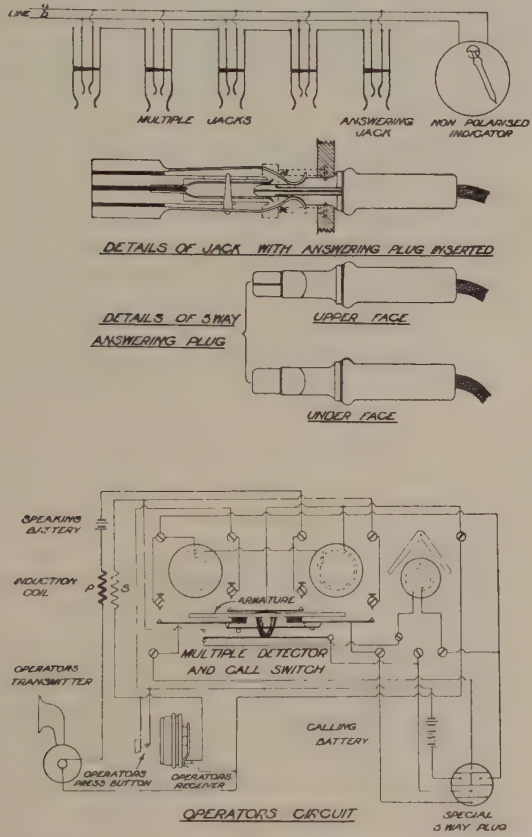

FIG. 116.—Connections of operator's apparatus, subscribers' line circuit and details of jack and five-way answering plug, N.E. (N) system, Newcastle-on-Tyne.

of the switch. The operator's set was then in direct connection with the subscriber's metallic circuit line, the subscriber's 1000w. indicator remaining in circuit in bridge.

(*d*) On the operator being informed by the calling subscriber of the number wanted, the answering plug was withdrawn, and the detector switch needle assumed its normal position. If the

wanted subscriber's local equipment was situated at another section, the operator inserted the answering peg in the respective multiple jack. If the required subscriber's circuit terminated on the same section, the answering peg was placed in the answering jack.

(*e*) If engaged, the right hand needle of the detector gave a deflection to the left, and in this event the operator again plugged into the calling subscriber's answering jack, and informed the waiting subscriber that the subscriber he wished to communicate with was engaged.

(*f*) If disengaged, the indicator needle of the detector and call switch deflected to the right, and thus gave to the operator indication that the connection might be proceeded with.

(*g*) The button on the operator's handset was then depressed and the circuit of the coils of the detector switch became closed. The switch again operated and the contacts made had the effect of augmenting the permanent current circulating in the line; the bias of the subscriber's relay was overcome, the relay operated, and rang the local call bell.

(*h*) On the called subscriber answering, the needle of his indicator situated at the home position was immediately deflected from right to left, incidentally giving to the operator at this section of the board an indication that the particular subscriber's line had been engaged at another position. The subscriber was then informed by the operator of the impending call, and the connection was completed by the operator first withdrawing the five way peg and afterwards taking from a rack a simple two way connecting cord and inserting the pegs at either end thereof, one in the calling subscriber's answering jack, and the other in the multiple jack of the called subscriber. The two subscribers were then in direct communication.

In practice, it was customary for the operator to insert one peg of the connecting cord in the calling subscriber's answering jack, immediately after withdrawing the answering peg, for the purpose of testing the line and calling the required subscriber. During conversation, both subscribers' indicators remained deflected to the left, thus giving an engaged signal at each position.

(*j*) On cessation of conversation, when the subscribers hung up their receivers, and thus reversed the permanent current, the clearing signal was given by the needles of the two subscribers'

indicators reverting to the normal or right hand position, and the answering operator then withdrew, and replaced upon the rack, the connecting cord and restored normal conditions.

In case an operator desired to be informed of the release of a line which she had tested engaged in the attempt to satisfy an application made at her position, she would insert in the multiple jack a detector peg associated with the right hand needle of the third detector and call switch which would remain deflected to the left so long as the lines remained connected, but without interfering in any way with through conversation. When the subscribers cleared, the indicator needle moved over to the right, thus denoting that the required line was at liberty.

The operators' handsets employed in this switchboard were originally fitted with Moseley Granular Carbon Transmitters, an instrument patented by Mr. Charles Moseley, of Manchester, in May 1882. At a later date, these transmitters were replaced by instruments of the Deckert type.

Although the operation of the N.E. (N) system may appear cumbersome in comparison with present day operating methods, it is interesting to note that a day calling rate of 16·3 per subscriber was dealt with upon this peculiarly designed switchboard.

The N.E. (N) system possessed many features in common with the Post Office universal system, which it displaced at Newcastle-on-Tyne. A special feature of the Heaviside system as also of the Post Office Universal System, was the particularly fine construction and solidity of the whole of the switching plant and instruments. The indicators, multiple detector and call switch, the jacks and pegs were, in fact, of beautiful workmanship and finish, and were made at the Post Office factory at Holloway, London. It is safe to say that no telephone system in the world was fitted with equipment and apparatus which equalled in workmanship and finish that fitted on the switchboards of the Post Office at this time.

The N.E. (N) system had not a very long life. One of its chief defects was that it did not lend itself readily to inter-working with systems of different design. It was brought into service in Newcastle-upon-Tyne during the year 1889, and was replaced by a common battery signalling system between the dates April 26th and June 8th, 1906, during which period approximately

700 direct exchange lines were transferred from the N.E. (N) to the new system.

Fig. 115 is from a photograph of No. 1 Section of the N.E. (N) switchboard at Newcastle-on-Tyne and Fig. 117 is a general view of the switch-room. For both these photographs and for much information contained in this chapter regarding the N.E. (N) system, the author is indebted to Mr. G. E. Gilpin, late of the Post Office Engineering Department, Newcastle-on-Tyne. To Mr. C. Whillis also the author desires to express his indebtedness for valuable information and help rendered in connection with the preparation of this section.

FIG. 117.—General View of Post Office Switchroom, N.E. (N.) system, Newcastle-on-Tyne, 1905.

(From a photograph by Mr. G. E. Gilpin.)

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CHAPTER XII

THE INTRODUCTION AND DEVELOPMENT OF DRY CORE PAPER INSULATED CABLE—TERMINATION OF DRY CORE CABLES, 1890–1912

In Chapter VIII some of the early attempts made from time to time to produce a satisfactory method for the employment of underground conductors for telegraph and telephone purposes are described. All the systems mentioned in that chapter suffered serious disadvantages which precluded extensive use of them. Consequently the early growth of the telephone service was provided for almost exclusively by the use of open wires erected as required, and large and elaborate overhead systems very soon came into existence in all the larger towns and cities of the United Kingdom.

The numerous troubles and difficulties associated with the construction and maintenance of such systems are dealt with in other chapters of this volume. Development of the telephone service was so rapid and gave such promise that within a few years of the introduction of commercial telephony it began to be realised that the exclusive use of overhead wires, considered on the basis of the then available methods, appliances and materials, would not suffice for very long, and much consideration was, therefore, given to the production of a system of conductors in the form of cable suited to the requirements of telephone underground plant.

Owing to the great strides made in telephone development in the United States, the question there reached what may be termed a critical stage earlier than in this country. Even in that land of independence and liberty, the rapid growth in the thickly populated districts of overhead wires, for the most part supported upon poles fixed in the public streets, led to objection being taken to a continuance of the practice, and from several other points of view the provision of suitable means for placing

lines underground and to relieve the overhead congestion became imperative.

The scientific manner in which the cable problem, as well as other similar and no less difficult problems, was attacked in America, and brought to a successful issue by the invention of dry core cable, receives further mention in Chapter XXII.

Early cables used for telephone purposes were made up of wires laid parallel to one another; this was in the days when metallic circuits were the exception rather than the rule, and the inductive effect in cables carrying numerous circuits, when several were in use at the same time, was such as to render conversation almost impracticable.

A paragraph in Mr. J. E. Kingsbury's book "The Telephone in Principle and Practice—its Origin and Development," published in 1882, describes the situation at that time in regard to the use of underground wires for telephone circuits as follows :—

"As the telephone becomes more generally adopted the multiplication of overhead wires is a question which will doubtless have to be taken into consideration, for anyone walking along the City cannot fail to be struck with the network which is fast gathering. There is a general idea that they are a prevalent cause of accident, yet I think on investigation it will be found that accidents are extremely rare. Though we have recently experienced some of the most severe hurricanes known in modern times, I do not remember to have seen a single broken wire or to have heard of an accident. At present the telephone cannot be well worked with underground wires, as its sensitiveness to the induced currents from the adjacent wires renders its own message unintelligible; but as another instance of the way science keeps pace with the times, I think I may safely say it will not be long before we have a cable which will permit any number of telephone wires to be run alongside without suffering from induction, and that so soon as it is necessary to deal with the question the means will be at hand to provide the remedy."

Thus Mr. Kingsbury foretold the production of the present day type of telephone cable.

The great preponderance of subscribers' telephone circuits in this country were worked single wire with earth return until about 1892, when the work of converting them into metallic circuits was commenced systematically. The introduction in 1887 of the twisted pair for cable conductors had the effect,

eventually, of revolutionising line circuit practice, and paved the way for the extensive use of underground cables. The manufacture and use of such cables followed immediately, but did not help matters very much in regard to inductive disturbance experienced with single wire circuits. To carry on satisfactory conversation over single wire circuits conveyed in cables accommodating an appreciable number of working lines was not accomplished with ease; the babel of voices sometimes heard, although indistinctly perhaps, was most distracting and rendered the intelligible interpretation of conversation a matter of difficulty. This was the case even in the days of the Blake transmitter, an instrument which could not be termed powerful. On the introduction of the granular transmitter, attempts were in some instances made to use it in association with earth-completed circuits, but the increased inductive effect produced in lines accommodated even for short distances in underground cable was so great as to render its use impracticable under such conditions; consequently the application of the granular transmitter in this country was generally delayed until conversion from earth to metallic circuit working was effected.

The system of underground work devised by Mr. Cook, and adopted prior to the year 1843, for telegraph purposes on certain railways, and described in Chapter VIII, was virtually a dry core system. The point of difference between the modern paper core cable and Cook's system was that, whereas, in the former, dry air is utilised as the staple insulating medium (the paper being introduced merely to maintain the wires in separation), in Cook's system the insulation was in reality dependent upon the permanent covering which enveloped the wires, but that covering was nevertheless only rendered effective as an insulator by the presence of dry air.

It seems surprising that a period of nearly fifty years elapsed before the system was, in principle, revived, eventually to become standard for telephone cable practice the world over. The intervening period was provided for, in so far as essential underground circuits were concerned, by the trial of numerous expedients, most of which are described or mentioned in the chapter referred to. It is, however, a fact that until the resurrection of the idea of utilising dry air in conjunction with paper, as insulation for underground cable conductors, none of the

devices or methods employed could be regarded as satisfactory for telephone purposes, owing chiefly to the high specific inductive capacity of the materials selected as dielectric; also to the relatively large space occupied by such materials. Consequently, during this period progress in development was accompanied by extensive use of overhead wire, cable being laid only in unavoidable circumstances.

The origin of the dry core paper insulated cable really dates back to the year 1889. Prior to this date, for sheathed cables, cotton largely prevailed as the material employed for wire covering, and for insulation the cotton was impregnated with paraffin wax, resin, or other compound of similar properties, as mentioned previously.

It was soon realised that the chief difficulty to be overcome in the production of a cable suitable for telephone purposes was to effect an appreciable reduction of inductive capacity, and although the insulating materials previously chosen had more or less satisfactory insulating properties, unfortunately their specific inductive capacity was high.

Mr. W. R. Patterson, in the article alluded to in Chapter VIII, mentions that cable manufacturers realised that air gave a lower static capacity than any solid filler, but that nevertheless dry core cable came into use slowly. In referring to the manufacture of the Patterson gas impregnated paraffin-filled cable, which immediately preceded the true dry core cable, he states that "We had a 'private entrance' from the gas space above the paraffin in the charging tank and used to let in 'gas charged with paraffin,' instead of 'paraffin charged with gas,' when a very low capacity was required." He goes on to relate humorously how the first really dry core cable ever laid was, he had reason to believe, in New York. The cable conduit was so close to the mains of the steam-heating company that the paraffin would remain melted. He says: "We could not guarantee a high insulation; on the contrary, we could guarantee that the insulation would be low and get worse, since the paraffin would deteriorate in time if kept at a high temperature. We advised the purchaser to 'leave out the filling.' We were told that the pipe must be filled and, if paraffin was not suitable, to use something that was. We used air. We plugged the ends of the cable with a sticky mess of resin and oil, but we did not tell the

customer that that kind of filling extended only about three feet, until some companies mustered up nerve to order 'dry core cable.' "

The use of paper as covering for cable wires was first suggested in 1889 by Mr. J. A. Barrett, electrician to the American Telephone and Telegraph Company, who, in conjunction with Mr. W. D. Sargent, of Brooklyn, had conducted experiments made with the intention of securing lower capacity, by the use of a material other than cotton and which demonstrated the success of manilla paper. It was, however, left to Mr. W. R. Patterson, of the Western Electric Company, to put forward the suggestion that the lower capacity which resulted from the use of paper was due, not so much to any inherent property of the paper, but rather to the fact that the insulating compound did not so readily penetrate the pores of paper as of cotton and, therefore, that less air was expelled. He therefore recommended that the impregnating material should be omitted, except in places where the cable was likely to be subjected to mechanical injury. Hesitation to adopt at this period cable unimpregnated throughout its entire length appears to have been due to the opinion that the sheath of lead tin alloy adopted at that time could not entirely be relied upon as an effective seal against ingress of moisture to the paper core. Moreover, as no method was at the time available whereby moisture might be expelled from a cable into which, by some mischance, it had penetrated, the view held was that complete replacement of a faulty length would necessarily follow, an eventuality which, at that time, appeared to carry considerable weight.

In 1891 the benefits expected from the adoption of dry core cable in its entirety turned the scale in its favour completely, and cables of the true dry core type were immediately brought into use in America, and quickly became universal. Thus by the time the necessity arose for the use of large multi-wire cables, the problem had been solved on the other side of the Atlantic, and the facilities afforded by the American product were at the disposal of telephone administrations in this country.

A good deal of difference of opinion and discussion has centred upon the question of the choice of the most suitable material for the sheathing of cables. The Western Electric Company

from the first included a small percentage of tin with the lead, a practice adopted from an early date in the manufacture of lead pipe, and they continued so to do for many years. Antimony as alloy with lead was also experimented with at an early date, but tin was ultimately considered to be superior because an excess of antimony produced a sheath which was too brittle, whereas an excess of tin was not prejudicial mechanically, although, of course, it added to the cost. For some time, therefore, American engineers advocated and employed a lead-tin alloy and a sheath of similar composition was adopted by the National Telephone Company.

The increasing price of tin led, however, to a revival of the question, a series of investigations extending over a period of some four or five years was entered upon, and a wide range of alloys was studied. These alloys consisted generally of lead and antimony, lead and bismuth, triple alloys of lead, nickel and copper, and of lead, tin and antimony in various proportions. Some fifteen or twenty different alloys were considered in relation to their ability to resist bending, vibration and chemical and electrolytic corrosion. The most promising of these alloys were selected and used experimentally for the sheaths of certain "test lengths" of full size cable, 400 to 500 feet long. These lengths were placed under trial in various ways. Some were repeatedly drawn in and out of duct ways and the results observed. Other lengths were placed on bridges, where they were subjected to vibration, and their behaviour noted, in order to determine the ability of the respective alloy to resist vibration without crystallisation or fracture.

The final result was the adoption, some ten years ago, of a sheath composed of an alloy of 99 per cent. lead and 1 per cent. antimony, and this remains the standard commercial practice in America at the present time. The adoption of antimony in alloy with lead resulted in a satisfactory reduction in the first cost of cables, and it is understood that a further saving is anticipated from an adjustment in the thickness of the sheath, a matter at present under consideration.

The British Post Office, on the other hand, adopted and still specify a sheath of new British or Colonial pig lead as more ductile and offering more resistance to electrolytic and chemical corrosion than the alloy.

While lead has the advantage in pliability and in facility of bending, for tensile strength and hardness the alloy has the advantage. So far as cost is concerned, lead appears to have the advantage for a sheath of given thickness and the alloy for a sheath of given tensile strength; in ability to resist corrosion the advantage is problematical.

The Fowler Waring Cable Company were the pioneers of the manufacture of lead-covered underground cables for telephone as well as for other purposes in this country. Sir John Fowler secured the English rights for manufacture of the so-called bituminous cable, referred to in Chapter VIII, and he formed a company known as the Fowler Waring Cable Company, Ltd., with works at North Woolwich. Cables for electric light and power purposes were the principal product, but the manufacture of dry core paper cable was also undertaken at a later date. As the Western Electric Company of America were anxious to manufacture cable in this country, in order to avoid shipment of the manufactured product from America, arrangements were made for acquisition of the Fowler Waring Company, which passed into their hands on December 31st, 1897.

Dry core cable was first used in this country in 1891. Some doubt exists as to the locality in which the first dry core cable was laid, but a mile and a half of 52 pair 20 lb. cable was drawn into a 3 inch cast iron pipe between Pipewellgate and Deckham, in Gateshead, and was brought into use early in the year mentioned. The joints in this cable were treated with lime as hereinafter described. About the same time two 41 pair 20 lb. conductor dry core lead-covered cables were laid between Liverpool and Birkenhead through the Mersey Tunnel, and replaced the anti-induction lead-covered cable previously laid in 1885, of which mention has been made. These cables were laid under the direction of Mr. Turney, of the Western Electric Company, the manufacturers. The joints were "boiled out," a process introduced by the Western Electric Company, not continued at the time, but which has since become universal practice in America, and has been adopted to a limited extent in this country, as will be described later. It is interesting to note that the continuity of the conductors at jointing points was maintained by an unsoldered twist, as at present, enveloped by a braided cotton sleeve impregnated with paraffin wax, which

again is the latest practice in America, although not in this country, where the paper sleeve is still used.

Numerous other cables of similar type were laid about this time in Sheffield, Birmingham, Liverpool, and other places; dry core cable quickly superseded the types of cable previously used for underground purposes and became universally employed.

British telephone engineers are now so well accustomed to the manipulation of dry core cable of all classes that it is perhaps difficult to realise how the new departure was looked upon when first it was installed in this country. Dry core cables were something entirely different from anything that had gone before and there existed a certain amount of diffidence in undertaking the complete work of installation. Engineers in this country had no previous experience in their manipulation, and consequently the process of jointing was looked upon as work which should be carried out by the manufacturers who, therefore, at first undertook the jointing, and were responsible for the electrical constants of the finished cable.

Improvements in the design and manufacture of dry core cable rapidly followed its introduction. In the earliest cables conductors were somewhat heavily enclosed with paper, and consequently the external diameter was not less than $2\frac{1}{2}$ inches. Improvements first introduced were in the direction of increasing the number of pairs accommodated, accomplished by reducing the amount and thickness of paper wrapping and sacrificing to some extent the air space.

Upon its invention in 1891, dry core cable might accurately have been defined as a series of copper conductors individually enveloped by a loose wrapping of paper, the whole suitably grouped and enclosed in a lead sheath or tube. In principle there has been no radical change in the constitution of dry core cable and the same definition holds just as good to-day as it did when dry core cable was first made. Modifications made in its construction have merely been variations in the arrangement, number and gauge of the wires, the amount and thickness of the paper insulation, and the composition and thickness of the lead sheath. Consequently, during the thirty-three years dry core cable has been universally used for telephone purposes, there has been no material alteration in its construction, and historically there is little to record.

In the earlier cables, the paper enveloping the conductors was applied in the form of one or more simple spiral wrappings, alternate layers being laid in reverse directions, some with, some without the addition of a cotton thread or threads, laid in reverse spiral to the paper it enclosed, in order to prevent the wire from readily bursting through its covering.

Various expedients were tried from time to time by different manufacturers of dry core cable in the application of the paper covering to the conductors; one of the principal objects was to secure a reduction in electrical capacity by an increase in the air space in proportion to the amount of paper used. Developments eventually led to the final adoption for subscribers' cables of a conductor enveloped in a single strip of manilla paper applied to the wire either longitudinally or spirally. Manufacturers were generally permitted to adopt either method, but the use of a cotton thread laid spirally over the paper was stipulated for longitudinal coverings.

Jointing by the Western Electric Company of the first dry core cables laid in this country was accompanied by the boiling out process, in which the completed joint was treated with hot wax, poured over it in order to remove moisture absorbed during the jointing process. The practice was, however, not continued for very long, and desiccation of joints during construction and after completion, but prior to plumbing, was afterwards effected by applying to the jointed wires finely powdered lime, previously heated in order to expel moisture. The lime, while hot, was held in position by thicknesses of brown paper temporarily arranged so as to envelop the joint, and was afterwards shaken out, to be redried and used again, except in the case of final application, when all that remained after removal of the paper envelope was enclosed within the lead sleeve, afterwards secured by plumbing over the joint. Wires in cableheads were similarly treated.

Upon the introduction generally of the process of desiccation by means of dry air, the practice of using lime, originally introduced by the Fowler Waring Company and practised by the jointers of that firm, was discontinued in 1897–1898. It was found that not only was the lime a hindrance to the free passage of air, but, if water did penetrate to a joint treated with lime, the effect was much worse than if the lime had not been present,

as may be readily imagined. Heating by brazier or by plumber's lamp proved to be a superior method of drying joints prior to the final plumbing operation.

In the year 1896 manufacturers were in a position to supply dry core cable in larger quantities; thereafter a great expansion in the use of such cable in this country took place, and much activity prevailed in the installation of underground plant. Dry core cable played an important part in the work undertaken at about this period of doubling the existing earth circuit subscribers' lines throughout the country, in substituting large quantities of overhead wire and in making generous provision for prospective development.

In 1895 cables containing as many as 153 pairs of 20 lb. conductors were introduced to be quickly followed by 204 pairs of 20 lb. cables.

In August 1897 the National Telephone Company placed its first large contract for telephone dry core cable with the Fowler Waring Cable Company, and some of the provisions of this contract are not without interest.

The Fowler Waring Company were to supply experienced jointers for jointing the cable, and they had the option of supervising the laying operations.

Conductors were to have a diameter of not less than 35·5 mils. and not more than 36·5 mils., and the resistance was not to exceed 44 ohms per mile at 60° F. One conductor in each layer was to be distinctively marked for purposes of indentification.

The core was to be enveloped with a thin and open covering of cotton braiding, and the whole enclosed within a sheath of lead-tin alloy, containing not less than 3 per cent. of tin, with minimum and maximum thicknesses of 120 and 135 mils. respectively, and it was to be capable of withstanding an internal air pressure of 75 lb. per square inch. The insulation resistance was to be not less than 500 megohms per mile, measured with the sheath and all other wires connected to earth.

The electrostatic capacity was not to exceed an average of 0·075 microfarad per mile, measured with the sheath and all other wires connected to earth, and the capacity of any wire so measured was not to exceed 0·080 microfarad per mile.

One end of each length of cable was to be filled up solid for a distance of 12 inches with approved insulating substance to

enable clip screws to be inserted (for drawing in purposes), without allowing moisture to pass into the cable.

The sizes and external diameters of the respective cables were as follows :—

Size of cable in pairs.	Outside diameter in inches.	
	Minimum.	Maximum.
204	2·375	2·500
153	2·375	2·500
102	1·875	2·100
77	1·625	1·800
52	1·375	1·600
26	1·000	1·125

Dry core cable was not protected by patent, and its manufacture was quickly taken up by European manufacturers, in addition to the Western Electric Company, its originators. Amongst these was the British Insulated Wire Company, who commenced manufacture of dry core cable as early as 1891. The first cables manufactured by this firm were of the solid paper insulated type, in which successive ribbons of paper were spiralled round the conductors until the requisite thickness of insulation was obtained. They were lead-sheathed by means of a lead press. This class of cable was soon followed by improved types; the improvement aimed at was reduced electrostatic capacity and facility for desiccation, attained by a reduction in the quantity of paper used and a corresponding increase in the air space. Three early types of cable manufactured by the British Insulated Wire Company were as follows :—

(*a*) *" Barrier " Twin Type.*—In this cable a ribbon or " barrier " of paper separated the two conductors of a telephone pair. The barrier was twisted in order to give a definite " lay," and the pair of conductors was encircled with a tube of paper. A number of pairs thus formed were then stranded together to constitute a cable. An alternative method with this type of cable was to envelop each conductor separately with a loose paper covering applied longitudinally, and then to proceed as indicated above.

(*b*) *" Barrier " Quadruple Core Type.*—The section of the barrier in this case was in the form of a cross, the four conductors of the quad being placed one in each of the four quadrants

formed by the arms of the cross. The quad thus formed was enclosed in a longitudinal paper wrapping and several cores were stranded together to make up the cable.

(*c*) "*S*" *Twin Type.*—As implied by the description, the paper used to insulate a pair of conductors was so shaped as to present a cross-section like the letter "**S**." The conductors were laid in the loops of the **S**, and the longitudinal edges of the paper were pressed back so as to form two closed tubes. Amongst the most interesting of the orders executed by the British Insulated Wire Company for cables laid up in barrier form were, one for some 2 pair 100 lb. "Barrier" quadruple core cable for connecting into the London Paris trunk telephone system, and one for some 200 pair twin "Barrier" type insulated cable for the Glasgow underground lines. In 1896–1897 some 38 pair 100 lb. cable was manufactured by the British Insulated Wire Company for the first underground London-Birmingham trunk route, part of which was the plain Barrier twin type and part the Barrier quadruple core type.

British firms who have from time to time taken up the manufacture of telephone paper core cable in this country are named below :—

(1) Western Electric Co., Ltd., North Woolwich, E. 16.

(2) British Insulated and Helsby Cables, Ltd., Prescot, Lancashire, and Helsby, Cheshire.

(3) Siemens Bros. and Co., Ltd., Woolwich, S.E. 18.

(4) W. T. Henley's Telegraph Works Co., Ltd., Blomfield Street, London Wall, London, E.C. 2.

(5) Johnson and Phillips, Ltd., 12 Union Court, London, E.C., and Old Charlton, London, S.E. 7.

(6) Callender's Cable and Construction Co., Ltd., Hamilton House, Victoria Embankment, London, E.C. 4.

(7) W. T. Glover and Co., Ltd., Trafford Park, Manchester.

(8) Pirelli-General Cable Works, Ltd., Southampton.

(9) Union Cable Co., Ltd., Dagenham Dock, Essex.

(10) Hackbridge Cable Co., Ltd., London Road, Hackbridge.

(11) Enfield Ediswan Cable Works, Ltd., Mill Marsh Lane, Brimsdown.

Foreign firms in Europe who have supplied dry core paper cables for telephone purposes to British Telephone Administrations are named below :—

(1) Société Industrielle des Téléphones, Beyons (nr. Paris) and Calais.
(2) Felten & Guilleaume, Mulheim (nr. Cologne).
(3) Algemeine Elektricitäts Gesellschaft, Basel.

The first main underground line of air-space paper core cable of appreciable length to be laid in this country was one provided by the British Post Office between London and Birmingham, a distance of 117 miles. For about a quarter of this distance, that is, between Cricklewood and Edlesborough, the cable contained 76 wires weighing 150 lb. per mile, laid up in fours, but for the remainder of the distance twisted pair formation was adopted. The wire was 97 mils. in diameter with a maximum resistance of 5·852 ohms per mile. The lay in twisting was 12 inches and the insulation a longitudinal wrapping of paper. The composition of the layers to form a 38 pair cable was 1, 6, 12 and 19. There were lappings of paper between the layers and between the outer layer and the lead sheath. The lead sheath was 160 mils. in thickness and the overall diameter of the cable slightly more than $2\frac{1}{2}$ inches. The cable was manufactured by the Western Electric Company and the British Insulated Wire Company. It was drawn into conduits consisting of lead-jointed cast iron pipes with an internal diameter of 3 inches, and was fitted with " test pillars " at intervals of five miles to facilitate the localisation of faults. The construction of the new line was commenced in 1897 and completed in 1899. Before being brought into practical use, exhaustive experimental work was carried out in order to ascertain the suitability of such cables for telephone and telegraph purposes. Particulars of some of these experiments are given in a paper, entitled " The Long Distance Telephone System of the United Kingdom," read by Sir William Noble, Engineer-in-Chief to the British Post Office, before the Institution of Electrical Engineers on March 17th, 1921.

For many years after the introduction of dry core cable 20 lb. conductors were regarded as standard for subscribers' underground circuits and consequently most of the dry core cable

manufactured then contained conductors of that gauge only. The transmission considerations which indicated the possibility of employing cable conductors of lighter gauge than 20 lb. per mile are dealt with in Chapter XVII. The transmission discoveries referred to in that chapter resulted in what amounted to a revolution in underground line practice. It became possible to design lines specifically according to their particular function and a prospect for the employment of conductors of various gauges was opened up. The first diminution made in the weight of conductor used in dry core cables for the accommodation of subscribers' circuits took place in 1903–1904, when wires weighing 12½ lb. per mile were introduced and cables containing as many as 306 pairs of wires began to be used. A further reduction in gauge occurred in 1904–1905 upon the introduction of 10 lb. conductors, followed in 1907–1908 by the successful manufacture and use of cables composed of wires weighing only 6½ lb. per mile. Mechanical considerations chiefly operate to restrict the use in certain circumstances of conductors of even lighter gauge than 6½ lb. The complexities introduced in problems of cable circuit distribution and the economical aspect of the employment in cable systems of wires of these mixed gauges are dealt with in Chapter XIX.

The general advances made in the design, construction and manufacture of dry core cable for the accommodation of subscribers' circuits from the time the Fowler Waring Cable Company was acquired by the Western Electric Company to the date when the National Telephone Company relinquished its responsibilities may be gathered from a comparison of the information recorded previously in this chapter relative to cables manufactured by the Fowler Waring Cable Company in 1897, and the five tables numbered 7, 8, 9, 10 and 11, which give the principal particulars of the several classes of dry core cable manufactured to the specification of the National Telephone Company in 1911. Modifications introduced in the design of cable other than those indicated in the tables are :—

(*a*) The provision of two pairs with distinctively coloured paper covering in each layer for purposes of identification.

(*b*) The abolition of the outer cotton braiding in favour of two wrappings of paper of not less than four mils. in thickness.

(*c*) The abolition of the solid end rendered practicable by the introduction of the steel wire mesh cable grip for drawing in purposes.

The largest cable with 20 lb. conductors manufactured in this country contained 400 pairs of wires and was manufactured by the Western Electric Company for the Post Office Engineering Department; it was laid at Kingston-on-Thames for the purpose of providing subscribers' lines in that locality.

In 1909, following American practice, consideration was given by the National Telephone Company to the benefits which would accrue from the adoption of the "boiling out" process, in association with the operation of dry core cable jointing. Trials were made with a few selected cases where new underground works were being installed. Amongst these places, Redditch was one of the first where the whole of the cable joints in entirely new, although small, underground cable systems were "boiled out." Although satisfactory results were obtained, the process was not universally adopted by the company, owing to the fact that the amount of construction work carried out during the few years prior to the transfer of the company's undertaking to the State, which took place on January 1st, 1912, was insufficient to justify the introduction of a new process. Although the so-called boiling out of paper core cable joints was adopted as standard practice in America, for the purpose of excluding moisture from the cable core, and wires exposed during jointing operations, and thereby securing the maximum possible insulation of the completed cable, the method has yet only been used to a limited extent in this country.

Termination of Dry Core Paper Cables

A problem of considerable importance and no little difficulty, and one which has constantly confronted the telephone engineer since the introduction of telephone dry core cable, is that of its satisfactory termination. In spite of the large amount of attention directed upon the question during the thirty-three years dry core cable has been in use, it still remains a problem for solution to-day, for no means of termination, which can be regarded as in every way satisfactory for either outdoor or indoor purposes, has so far been evolved.

The problem was and still is, therefore, to produce a cable termination which to be entirely satisfactory will fulfil the following conditions :—

1. Its life should be not less than that of the cable to be terminated.
2. It should be capable of withstanding the unavoidable disturbance or interference to which it may be subjected by workmen.
3. Its insulating properties should be such that the insulation of the cable to be terminated should not be appreciably lowered by its application.
4. It should form an air-tight seal to the dry core cable and should be capable of withstanding the air pressure of desiccation.
5. Its cost should be reasonably low.
6. The circuits terminated should be readily accessible for testing and other purposes, and
7. For external use, in addition to the above-mentioned requirements, cable terminals should be capable of withstanding climatic influences satisfactorily.

Early dry core cables laid in this country were terminated by means of what were known as cable-heads. An early form of this device is illustrated in Fig. 118. It consisted of a cast iron box or trough provided at one end with a brass nozzle through which the cable to be terminated was introduced, and to which the lead sheath was afterwards plumbed. The cable wires were connected in the inside of the box to terminals of brass which protruded through its two sides and from which they were insulated by ebonite bushes. An iron lid was secured to the body of the box by means of set screws and the joint was rendered air-tight by means of a washer of india-rubber or other suitable material. The terminals were provided with screwed nuts both within and without the box, to facilitate connection of the wires.

A similar but later type of cable-head is illustrated in Fig. 119. The cover was secured to the box by means of $\frac{1}{4}$ inch brass screws, and the faces of the cover and box were machine planed to secure an even surface for a washer of india-rubber, 1/16th inch thick, used to make the joint air-tight. The specification provided that the completed cable-head should withstand an internal

air pressure of 10 lb. per square inch, and the insulation between the iron body and the brass terminals was to be not less than 50,000 megohms. The screwed brass nozzle was tinned to

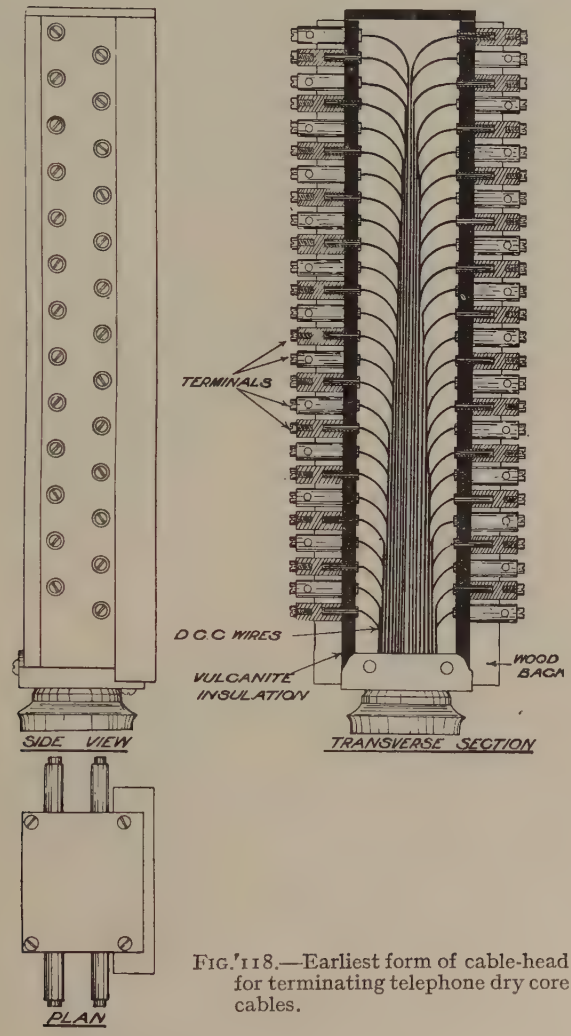

FIG. 118.—Earliest form of cable-head for terminating telephone dry core cables.

facilitate the subsequent plumbing operation. This type of cable-head was supplied in sizes accommodating 26, 52, 77, 102 and 153 pairs of terminals. For outdoor purposes, both the above types of cable-head required protection from weather,

and usually were enclosed in a suitable cover constructed of teak or other weather-resisting wood.

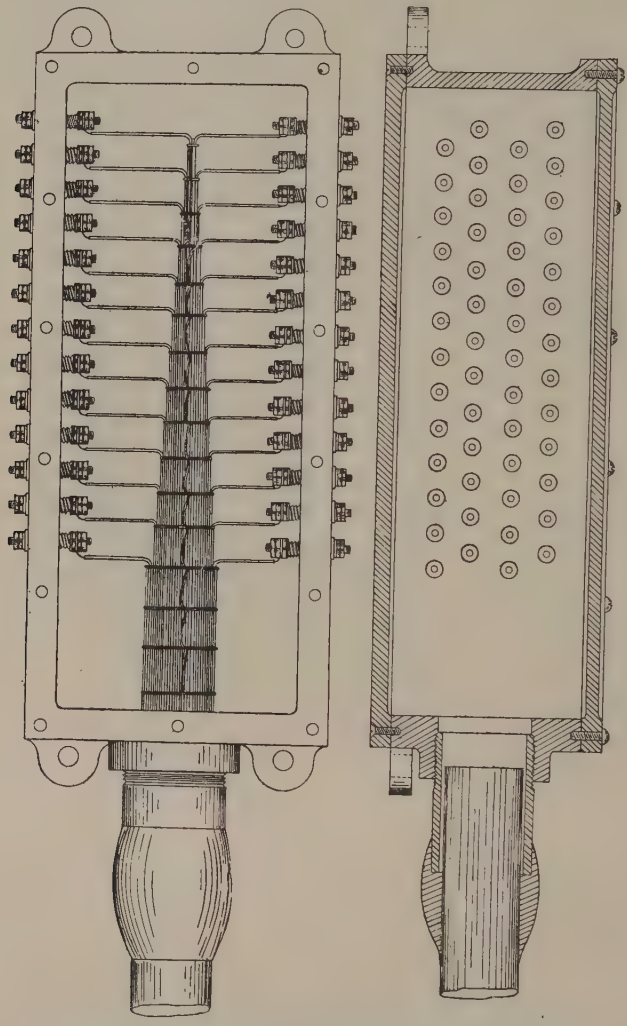

FIG. 119.—52-pair cable-head for terminating telephone dry core cables, 1891–1895.

In 1897, an improved form of cable-head was introduced by the National Telephone Company. It was constructed in two portions, known as "A" and "B," the latter fitted only when the situation was exposed to the weather. No wooden cover or

other protection was, therefore, necessary. The "A" portion was utilised for terminating the dry core cable, in a manner similar to that already described for the former mentioned

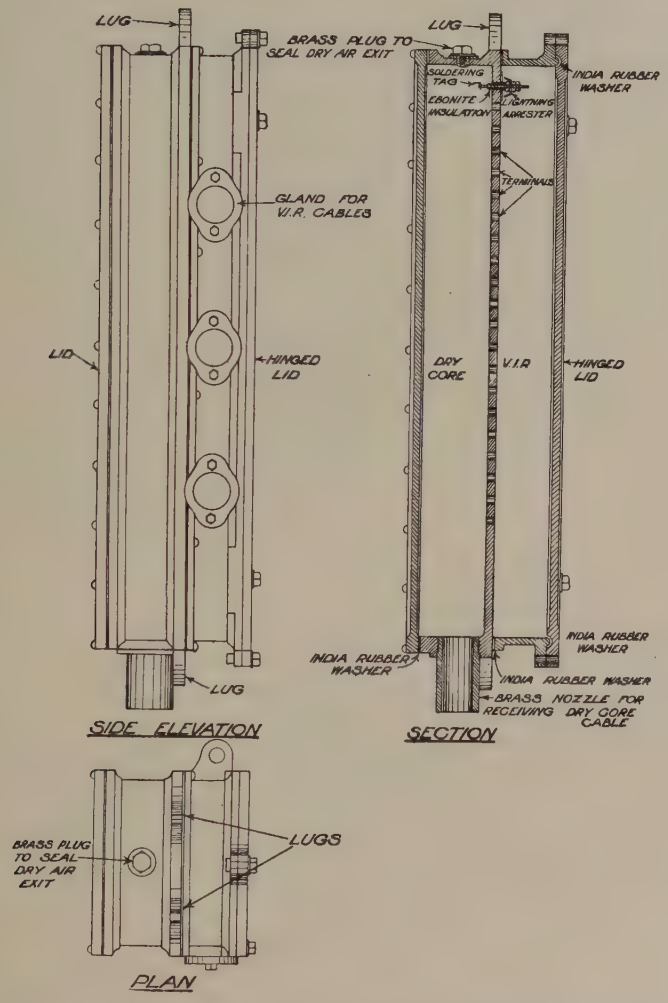

FIG. 120.—77-pair cable-head for terminating telephone dry core cables.

cable-heads, but the brass terminals, constructed so that each one constituted a lightning arrester for protection of the cable from lightning, passed through the bottom or back of the box instead of the sides. The "B" portion, when fitted, enclosed the outer extremities of the brass terminals, and afforded necessary

protection from the weather. Connection from the terminals to the outside wires was made by means of vulcanised india-rubber insulated braided cables of 20/10 wire which passed through glands provided in one side of the cable-head; these glands were suitably packed to exclude moisture from the interior. This type of cable-head is illustrated in Fig. 120, which shows the 77 pair size. Cable-heads of this pattern were made in sizes to accommodate 26, 52, 77, 102, 153 and 204 pairs of wires at the Nottingham Factory of the National Telephone Company. Fig. 152 shows a distributing pole bearing a cable-head of the type in question. They were much used throughout the whole country in the period 1896 to 1902, but in the latter year, owing to their high cost, the deterioration of the ebonite bushes and indiarubber washers and to the expensive nature of the braided cables used for opening out, they gave place to the pot-head.

Pot-heads for outside use were eventually constructed locally as shown in Fig. 121, and, after experience in their construction had been gained, and with care, gave satisfactory results. The principal objection to their use was that their construction involved the provision initially of expensive vulcanised india-rubber-insulated wires equal in number to the number of wires in the cable to be terminated; this included spares, and the whole were, therefore, subject to deterioration whether in use or not; also their initial cost was high. They had an effective life of from twelve to twenty years.

A pot-head terminating a 25 pair cable mounted on a distributing pole by means of iron clips is shown in the photograph reproduced in Fig. 122.

For terminating cables at exchanges and other similarly sheltered places, pot-heads of similar design were used, except that the "cap" or "shed" was omitted and the standard vulcanised indiarubber insulated wires were of lighter construction, namely, 22/15. The adoption of pot-heads in place of cast iron cable-heads enabled the dry core cable to be continued to a point in immediate proximity to the protector strips of the main frame or test cabinet, where they were terminated.

In about 1905 a new means of terminating dry core cables for outside use was introduced by the National Telephone Company. It was an importation from America, and was known

as the W. E. Type 14 cable terminal, a production of the Western Electric Company. It was somewhat similar in principle to, but an improvement on, the earlier forms of cable-head. Porcelain

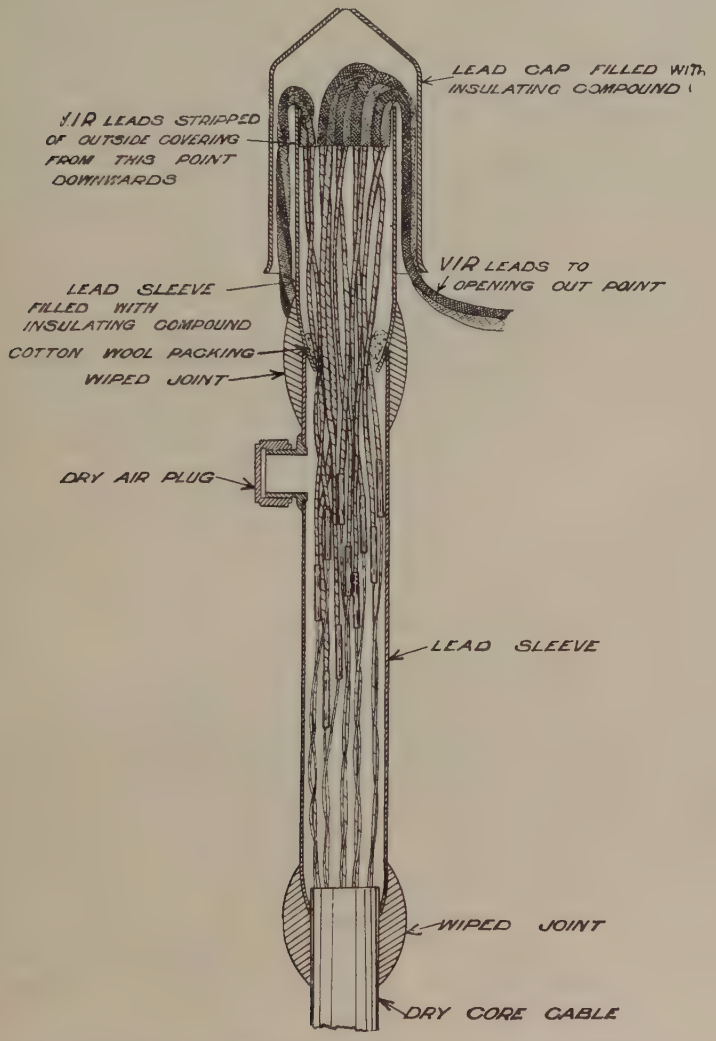
LEAD CAP FILLED WITH INSULATING COMPOUND
V.I.R. LEADS STRIPPED OF OUTSIDE COVERING FROM THIS POINT DOWNWARDS
V.I.R. LEADS TO OPENING OUT POINT
LEAD SLEEVE FILLED WITH INSULATING COMPOUND
COTTON WOOL PACKING
WIPED JOINT
DRY AIR PLUG
LEAD SLEEVE
WIPED JOINT
DRY CORE CABLE

FIG. 121.—Pot-head for terminating telephone dry core cables, 1900–1911.

blocks, through which passed brass terminals, were mounted in a box-shaped casting of iron provided with a hinged lid; into a recess at the back projected the inner ends of the brass

terminals, to which were connected the wires of a short length of lead-covered silk and cotton-insulated, wax-impregnated cable. The recess or cavity was sealed with a suitable compound, and the lead sheath of the silk and cotton cable was sweated to a gun-metal nozzle screwed into the box, through which it passed. Terminals were supplied ready fitted with silk- and cotton-insulated lead-covered "tails" after having been suitably tested, and in fitting them all that remained to be done was to make a simple joint between the dry core cable and the tail-piece. Connection to the open wires was afforded by means of short individual lengths of vulcanised india-rubber-insulated wire, installed only as required; they were passed through holes provided in the box for their individual reception, the unoccupied holes being normally sealed by pellets or discs of wax. These terminals were described and illustrated in a paper read by the author before the Birmingham Local Section of the Institution of Electrical Engineers on April 21st, 1909; the general practice of the National Telephone Company in cable construction at the date in question was described in this paper.

Terminals of this type continued in use up to the end of 1911, but they have been much more extensively used in the United States, where the general atmospheric conditions are perhaps more favourable to their maintenance in satisfactory condition than in this country. Although they gave satisfactory results, it was found that in course of time the brass terminals corroded, particularly in industrial neighbourhoods, where products of combustion and other chemical impurities were prevalent in the atmosphere. They were also subject to loss of insulation due to condensation taking place on the surface of the porcelain blocks and by deposit thereon of solid matter, chiefly carbon, from the atmosphere. It is believed that since the introduction of these terminals by the Western Electric Company they have been much improved and now constitute the standard open air termination for paper core cables throughout the United States.

Termination of dry core cables indoors was first effected by means of cast iron cable-heads similar in form to those described. When the type comprising the "A" and "B" portions was introduced, the "B" portion was omitted for internal situations. Cable-heads of this type to accommodate 204 pairs of wires were

FIG. 122.—Pothead for terminating Telephone Dry Core Cables, jointed to cable and mounted on pole.

(*From a photograph by the author.*)

[*To face page* 334.

the largest made; when cables of still larger size became available, cable-heads were abandoned and terminating was accomplished by means of pot-heads, as previously mentioned.

Particularly in the case of large cables it was extremely difficult to ensure that the pot-heads formed an air-tight seal to the dry core cable owing to the tendency for the formation of blow-holes or cavities in the compound used to fill the joint; the wires used for terminating were bulky and occupied a good deal of space on the test-boards or main distributing frames where they were terminated. After two or three years the pot-head for internal use gave place to the dry silk- and cotton-insulated lead-sheathed cable, introduced in 1900 and 1901. The joint between the terminating and dry core cables was filled with melted wax or compound to seal the dry core cable from the atmosphere and permit of its desiccation. That portion of the silk- and cotton-insulated cable to be opened out and connected to the soldering tags of the main frame was treated by immersion in melted beeswax, in order to sustain insulation and prevent absorption and penetration to the cable core of moisture.

The use of silk- and cotton-insulated cables for indoor terminations was a decided improvement on the pot-head, but the utmost care was needed in every stage of the process. Difficulties were experienced in maintaining the insulation of silk and cotton cable, and in rendering perfectly air-tight, by the filling process, the joint uniting the dry core with the terminating cable, and numerous expedients were adopted for the purpose of overcoming the difficulties encountered. Formation of air pockets or cavities by imprisonment of air in the compound during the filling process, and the condensation of moisture not excluded during the jointing operations, or expelled before plumbing, caused a good deal of trouble. Apparatus was devised for filling joints with compound or wax under air pressure, and the process employed to a limited extent with improved, although not absolutely reliable, results. Attempt was therefore made to remove to the factory the messy and difficult operation of sealing the cable *in situ*, by the introduction, in about 1910, of a terminating cable with silk and cotton insulation impregnated throughout its whole length with beeswax. This terminating cable was cut to the length required and supplied to the site of works, where it was stripped and laced out and jointed to the dry core cable

in the same manner as the dry silk and cotton cable. The process of waxing and filling the joint intervening between dry core and silk and cotton cable on the site of works was thus dispensed with.

Although in many ways a distinct improvement on the previous method, difficulties were encountered in the manipulation of the impregnated cable by reason of its rigidity and its resistance to facile bending; it was also found that in short lengths even the factory-filled cable could not be absolutely relied upon to form a perfectly air-tight seal. Nevertheless, no decided improvement upon this method for subscribers' cables has so far been forthcoming, and the practice remains up to the present time.

In passing, an interesting but extreme case of the termination of paper core cables under special circumstances at the National Telephone Company's Bank Exchange, London, may be mentioned. In Chapter X a fire which demolished the test-room at the exchange named is referred to. The emergency was such that extreme measures were warranted in restoring the service, and in re-equipping the new test-frame, the ends of the new dry core cables were directly connected to the soldering tags of the new test-frame, after suitable treatment with hot beeswax. The magneto system of working was in vogue at the Bank Exchange, and these cables gave satisfaction; installed as a temporary expedient only, their performance was such that they have remained in service up to the present time; as might be expected, however, their insulation is not of a very high order. For internal terminations of a minor character in London, other cases were similarly treated experimentally and satisfactory results were secured even where common battery working was in force.

The British Post Office first used cast iron cable-heads of somewhat similar design to those employed by the National Telephone Company and illustrated in Fig. 119, but terminals with much more substantial insulation were employed with the object of maintaining the insulation of the long distance circuits, for which they were principally used, at the highest practicable figure.

For outdoor purposes the Post Office has consistently advocated and employed lead-covered wires since the use of lead-covered cable became universal. The " solid plug," particulars of which are given in Fig. 123, was at one time largely used for the termina-

tion of 7 pair cables. The latest type of cable termination used by the British Post Office for external situations, known as a

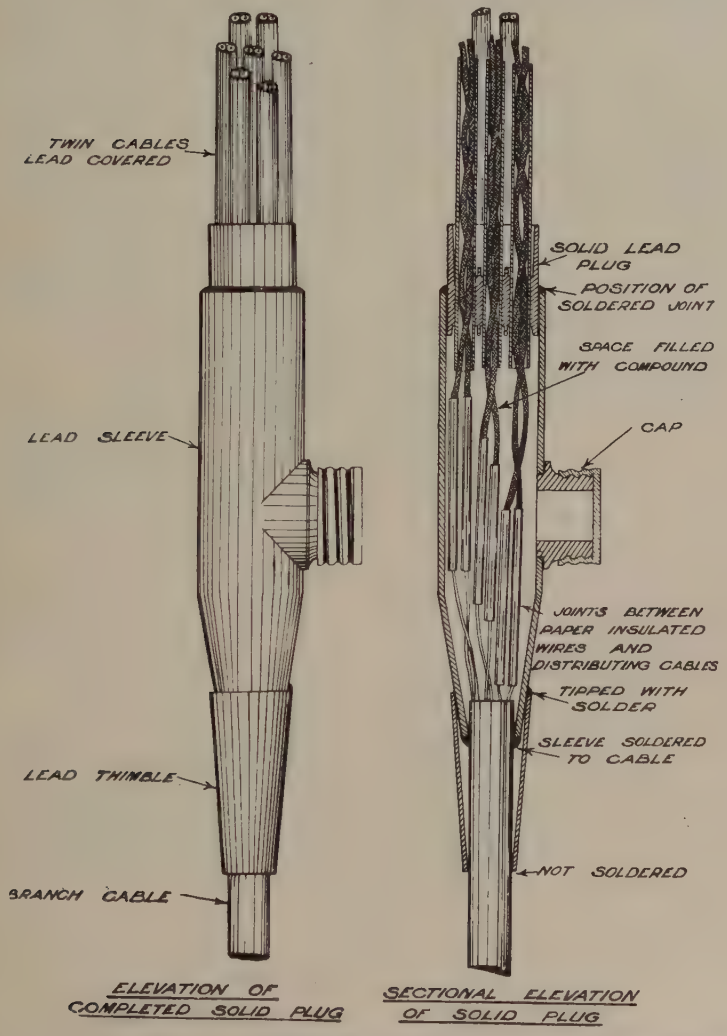

FIG. 123.—Solid Plug for terminating dry core cables as used by the British Post Office, 1902.

cable distribution plug, is illustrated in Fig. 124. It is used for terminating cables of various sizes up to and including 25 pairs of wires.

The various devices from time to time employed for the

termination of dry core cable have none of them been free from serious defects, and even to-day, after more than thirty years' experience with dry core cable, the means available for its

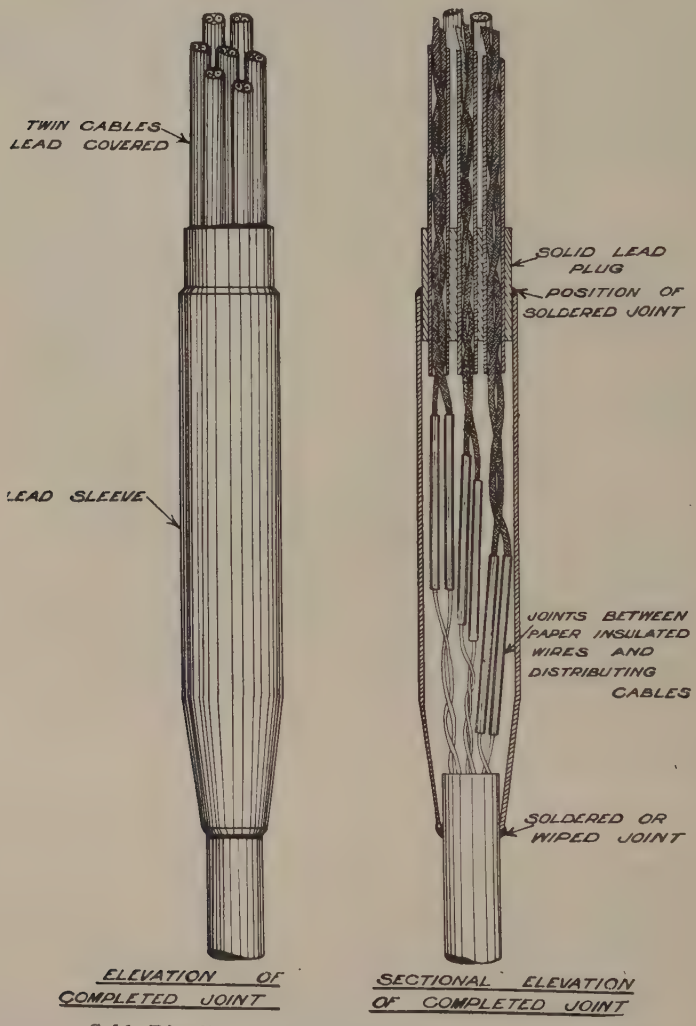
TWIN CABLES LEAD COVERED
LEAD SLEEVE
ELEVATION OF COMPLETED JOINT
SOLID LEAD PLUG
POSITION OF SOLDERED JOINT
JOINTS BETWEEN PAPER INSULATED WIRES AND DISTRIBUTING CABLES
SOLDERED OR WIPED JOINT
SECTIONAL ELEVATION OF COMPLETED JOINT

FIG. 124.—Cable Distribution Plug for terminating dry core cables as used by the British Post Office.

termination cannot be regarded as satisfactory. Terminations for outdoor situations, especially, still suffer from serious disadvantages and the production of an eminently satisfactory device should afford a profitable field for investigation.

CHAPTER XIII

INTRODUCTION AND EARLY DEVELOPMENT OF THE COMMON BATTERY SYSTEM, 1889–1922

THE common battery system, which now plays such an important part in the telephone service, not only of the United Kingdom, but of the whole world, was introduced into this country only after its practicability and superiority over the systems of working employed previously had been demonstrated in America, where it originated and was developed rapidly.

The primary purpose of this volume is to present a record of the introduction, growth and progress of telephony in this country from its inception up to the year 1912, and therefore it is not proposed to enter into an exhaustive account of the evolution of the common battery system in America. The full and interesting story of how the common battery system was evolved in America has already been told, and will be found in Chapter XXVI. of Mr. J. E. Kingsbury's book, "The Telephone and Telephone Exchanges," to which the interested reader is directed for the complete story.

The history of the common battery system in this country would, however, not be complete without some mention of the work done by American engineers in connection with the early development of this beautiful system of manual telephone switching, and therefore the chief events relevant to the production of the common battery system, culled principally from Mr. Kingsbury's work, will be briefly related.

In Chapter XXVI of this book, Mr. Kingsbury relates how, in America, for long distance work it was found necessary to supply separate instruments fitted with granular carbon transmitters owing to the Blake transmitters, then in general use for local service, not being adaptable for long distance conversations. Leclanche cells were found to be unsuitable, and cells of the Fuller type were therefore used. The cost of maintaining these

cells was particularly heavy, secondary cells were considered and experimented with and the question of the entire displacement of local batteries eventually arose.

At this time, that is, in May 1892, Mr. Hammond V. Hayes, of the American Bell Telephone Company, read a paper before the switchboard committee of the National Telephone Exchange Association (of America), entitled " Common Battery Exchange System," in which he described his invention for the concentration of all battery power at the central exchange.

As a result of the discussion which followed Mr. Hayes's paper, a small experimental common battery exchange was established in Boston in 1892. In June 1896, after progressive development of the idea, the first common battery system of moment to be established in America commenced to give service at Worcester, Mass. This installation was, however, a common battery signalling system only, lamps actuated by relays being employed as calling devices. Louisville followed, in September 1897, with another common battery exchange, embodying certain modifications and improvements of importance. There were three independent batteries for the Worcester and Louisville switchboards, one for relay operation and supplying current to subscribers' transmitters, one for supervisory lamps and another for the line lamps and operators' transmitters. Cut off relays and supervisory relays and lamps were introduced with the Louisville equipment. In 1898, the three-voltage type of equipment was abandoned in favour of a single voltage system.

Other common battery switchboards quickly followed the Worcester and Louisville boards, and by 1901 there were about 14 common battery exchanges in operation in America.

Thus the common battery system was virtually the outcome of an attempt to supply subscribers' transmitters with current from secondary cells, situated at the central exchange, and for the purpose of eliminating the excessive costs of maintaining batteries at subscribers' premises; the common battery system may be regarded as having attained a practical form in 1892.

The system of working adopted by the London and Globe Telephone and Maintenance Company, devised and patented in 1882 by the electrician to the Company, Mr. G. L. Anders, is described in Chapter III. In this system the use of local batteries at the subscribers' stations was entirely dispensed with by utilising

a common central battery for signalling purposes, and a series of central batteries, associated with cords and plugs, for supporting conversation between subscribers. Anders's system could only be termed " common " battery in the strictest sense in so far as signalling was concerned, a separate but nevertheless central battery being employed for speaking purposes for each connection established at one and the same time. However, the common battery idea was there, only to reappear and to be highly developed in America after the lapse of some ten years.

Patents for common battery working were registered in this country for the Western Electric Company by Mr. J. E. Kingsbury. The first of these inventions was described in British Patent Specification No. 8222, of April 25th, 1895; provision was made for the operation of an annunciator or indicator when the subscriber removed the receiver from the switch-hook. The subscriber's instrument was fitted with a condenser and a high resistance bell, and the operator was provided with two clearing annunciators, one for each side of the double cord.

British Patent Specification No. 11548, of June 13th, 1895, provided for a telephone system in which incandescent lamps were arranged to serve as indicating devices. In one case, the calling lamp was caused to glow by the action of the subscriber in removing the receiver from its hook; by that operation a local battery was joined in series with a battery situated at the exchange, the latter being of itself of insufficient voltage to illuminate the lamp. In a modified arrangement, the whole of the illuminating battery power was placed at the central exchange. The lamps were interposed in the line circuit and, being operated directly without relays, their illumination would be affected by the varying resistances of the different subscribers' lines.

The operation of incandescent lamps by means of relays is now so commonplace and so reliable, that it may be difficult to appreciate that the suggestion to employ relays for the purpose was at first regarded with suspicion. Doubt existed as to the reliance which might be placed upon their actuation, particularly in regard to the reliability of the contact points to be operated.

The invention in 1895, by Mr. Mark A. Edison, of Chicago, of the " knife-edge " relay dispensed with the mechanical hinging devices generally associated with the armatures of relays, and, confidence in their ability to function properly ultimately

established, they were introduced generally for common battery working with entirely satisfactory results.

A further British Patent Specification, No. 11549, dated June 13th, 1895, made provision for the operation of lamps by means of relays, and included details of the type of relay and lamp to be employed. Several circuit arrangements were described.

Relays played such an important part in the operation of the common battery switchboard, ultimately produced by the Western Electric Company, that it was first described as the " No. 1 Relay Switchboard."

As already implied, the common battery system of working did not come to this country until the various improvements cited together with many others, had proved satisfactory and had been generally introduced in America.

In a paper entitled " Telephones " delivered before the Society of Arts on April 12th, 1899, Mr. John Gavey, then Assistant Engineer-in-Chief and Electrician to the British Post Office, gave a brief description of the Western Electric Company's common battery system of telephone switching as developed up to that date, and he exhibited a model of the system. He mentioned incidentally that the principle of automatic calling and clearing practised by the Post Office, in connection with the telephone system adopted by that administration (referred to in Chapter V of this volume), had been embodied in the Western Electric Company's system, but that the progress of modern discovery had placed at the command of telephone experts improved methods, of which they had availed themselves, referring, no doubt, more particularly to the utilisation of lamps actuated by relays for signalling purposes.

The Electrician for July 14th, 1899, referred to the paper delivered by Mr. Gavey before the Society of Arts and announced that the National Telephone Company had already in hand at Bristol the construction of an exchange in which the common battery system was being adopted, and a detailed description was given of its technical features, accompanied by circuit diagrams of the subscribers' apparatus, switchboard connections and cord connections.

The first common battery multiple switchboard to be installed for practical use in this country was at the Woolwich works of the Western Electric Company. It was erected in 1899 as a

FIG. 125.—Western Electric Company's Demonstration Common Battery Exchange, North Woolwich.

(From a photograph supplied by Mr. E. S. Byng.)

[*To face page* 343.

demonstration model, for the purpose of illustrating in a practical manner to engineers of the National Telephone Company, the Post Office and others interested, the principles of the operation

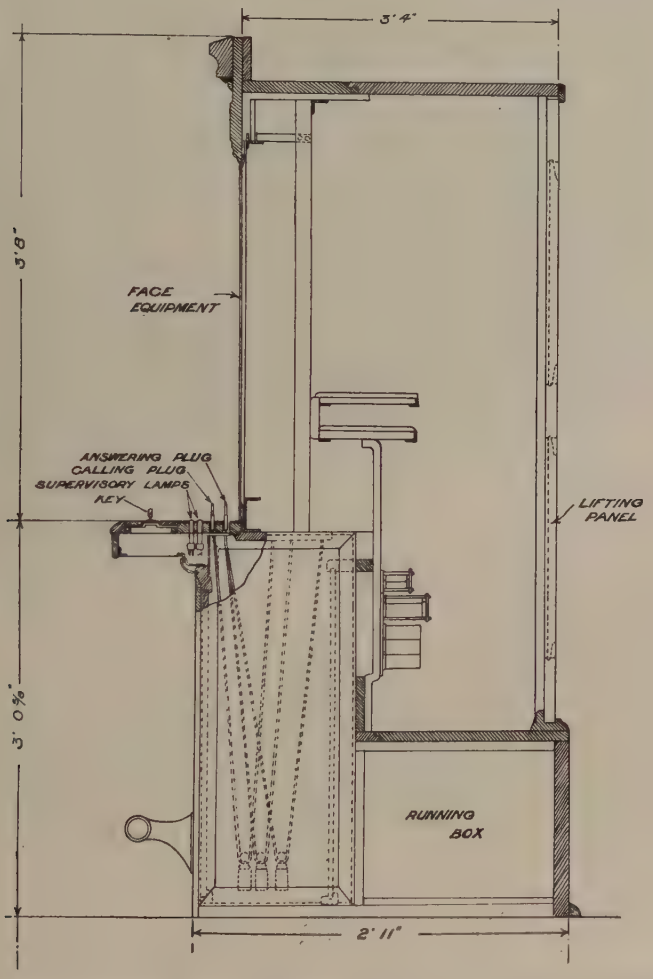

FIG. 126.—Transverse Section, Western Electric No. 1 Relay Switchboard, Bristol, 1899.

and working of a public common battery exchange. It was replete with all the essential components of a large exchange, including main distributing frame and intermediate distributing frame, and was fitted with a multiple for 40 lines. An illustration

of the switchboard, supplied by Mr. E. S. Byng, of the International Western Electric Company, is given in Fig. 125.

In 1899, the construction of the first common battery switchboard for public telephone service in Europe was commenced

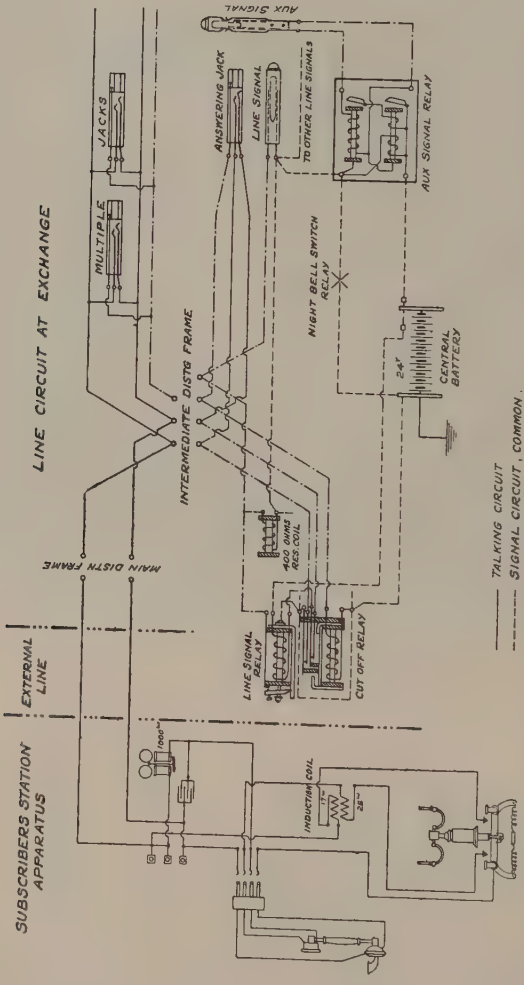

Fig. 127.—Subscriber's instrument and line circuit connections, Bristol No. 1 Relay Switchboard, 1899.

for the National Telephone Company at Bristol. It was installed by the Western Electric Company under the immediate surveillance of Mr. E. A. Laidlaw, of the National Telephone Company. Its initial capacity was for 1800 subscribers' lines and a junction section of three positions. A fully equipped two position exchange

manager's desk was also installed. The answering jack equipment originally fitted was for 100 subscribers' lines per operator, but, as a result of the better knowledge regarding operators' loads obtained as a result of the investigations conducted in traffic matters generally, the load per operator was subsequently increased to 140. The new switchboard was opened for service on Easter Sunday, April 15th, 1900.

The equipment provided for automatic signalling, automatic supervision and central battery transmission. Full particulars with drawings and diagrams of the " Relay Switchboard No. 1 " erected at Bristol have been kindly supplied to the author by the Western Electric Company and from them have been selected the reproductions in Figs. 126, 127, and 128, as indicative of the salient features of the equipment. Fig. 126 is a transverse section of the switchboard. Fig. 127 is a combined diagram of (*a*) the subscribers' instrument connections and (*b*) the line connections at the exchange. Fig. 128 shows the operator's cord circuit connections for a subscriber's section.

Views of the switch-room and of the National Telephone Company's Exchange building at Bristol, from photographs taken in 1900 and kindly supplied by Mr. Alfred Perkins, the company's district manager at Bristol at that time, appear in Figs. 129 and 130 respectively.

The Bristol switchboard was installed by the National Telephone Company partly as an experiment in order that the performance of the common battery system under actual working conditions might be kept under observation and the experience gained utilised as a guide in deciding future policy. The results of the working of the new system were watched with interest by telephone experts on this side of the Atlantic.

Although there were associated with the common battery system at this period certain difficulties to be overcome, it was a decided advance on the magneto signalling system which it displaced first at Bristol, and afterwards at various other places. As described in Chapter XI, a system of signalling by means of lamps was introduced into this country by the National Telephone Company soon after 1895, but it was not accompanied by automatic calling and clearing for subscribers' lines as was the common battery system installed at Bristol. Automatic signalling by means of lamps for subscribers' circuits was a great innovation,

and bestowed decided advantages both upon the subscribers and the telephone administration. Not only was the subscriber relieved of the necessity for the deliberate action of "ringing up" and "ringing off," but the necessity for relying upon him

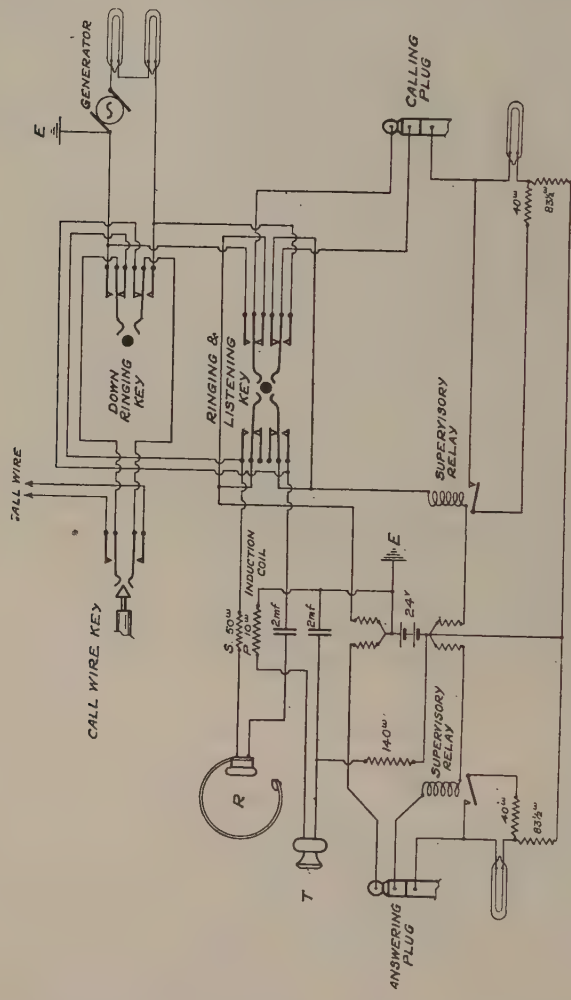

FIG. 128.—Cord Circuit, Bristol No. 1 Relay Switchboard, 1899.

for the latter operation was entirely removed, and replacement by hand of actuated calling and ring-off indicators on the part of the operator was also obviated. The double supervision provided by the two supervisory or clearing lamps was also decidedly advantageous, and tended to avoid the too frequent

FIG. 129.—General View, Bristol Common Battery Exchange, 1900.

(From a photograph by Mr Alfred Perkins.)

[*To face page* 346.

FIG. 130.—National Telephone Company's Exchange Building, Bristol, 1900.
(From a photograph by Mr. Alfred Perkins.)

[*To face page 347.*

breaking in by the operator with the inquiry, "Have you finished?"

The lamp signal in itself was an important advance. Its operation was unaccompanied by any noise, as was sometimes the case when the armature of an ordinary electro-magnetic drop indicator was agitated by the alternating current from the subscriber's magneto, but its glow was particularly assertive and attracted attention more effectively. It was not affected by vibration; it was compact and might be fitted in any position. The close association of the calling lamp with the answering jack, immediately under which it was placed, was an advantage which accrued by reason of the small amount of space it occupied. It was the reverse of complex, and its working parts, in the form of the relay which operated it, might be entirely removed from the switchboard and placed in a more readily accessible position where its maintenance was facilitated.

There were also other most important advantages secured by the common battery system. The subscribers' apparatus was simplified and rendered less costly, and the necessity for maintaining a battery and a magneto generator at subscribers' simple stations was removed. Transmission was generally improved in so far as the central battery ensured uniformity of voltage at the transmitter terminals and the line was subjected to constant voltage test. The service rendered was also generally improved by virtue of the introduction of automatic signalling with double supervision.

The second common battery exchange to be opened in this country was that of Hull, brought into service in March 1901, to be followed by Sunderland, where an exchange with equipment similar to that of Bristol commenced to operate on August 3rd, 1901, the latter occasion being commented upon in the following Wednesday edition of the Sunderland *Daily Herald and Post.* The circuit arrangements and general design of the equipment were similar to those of the Bristol board.

The next common battery exchange to be opened in the United Kingdom, and the first in London, was Kensington, in December 1901.

An exchange with a central battery was also opened at Nottingham in June 1901, but at first the common battery was employed for signalling only (automatic calling and clearing), local batteries

being retained to feed the transmitters at subscribers' stations. The equipment was so arranged as to facilitate the later conversion to full common battery working which transpired in 1904–1905.

In view of the numerous advantages derived from the common battery system, its superiority over other methods of switching was quickly established, and the National Telephone Company adopted it as the standard for new exchanges of importance.

Shortly after the introduction of the common battery system into this country, preparations were made by the British Post Office to institute a telephone system in London, competitive with the then existing system worked by the National Telephone Company, and as the success of the common battery system was then a proved fact, it was adopted by the Post Office for their large exchanges; the first to be opened, at Carter Lane, was equipped with a Western Electric Common Battery switchboard.

The improvements and modifications made to common battery equipment since its first introduction to this country at Bristol, in 1900, have been of but minor importance, and it speaks well for the design and circuit arrangements evolved at that date that the common battery manual system of to-day remains substantially what it was when it first came to this country.

The Western Electric Company held the principal patent rights for the common battery system, and quickly organised to provide for the needs of telephone administrations who decided in favour of the provision of common battery equipment. The National Telephone Company adopted generally the Western Electric Company's system and consequently the No. 1 type common battery exchanges established in this country were very similar in design and arrangement of circuits. An exception was, however, made in the case of Battersea, London, where in June 1902 a switchboard of the Kellogg type was brought into use. The equipment did not, however, differ greatly from that of the Western Electric Company, and does not call for detailed treatment.

Fig. 131 illustrates in a general way the chief modifications made in the Western Electric Company's common battery line circuits since the introduction of the system in Bristol in 1900. Fig. 131(*a*) is a skeleton diagram, considerably simplified, of the original subscriber's line circuit as employed at Bristol.

One of the first difficulties met with in common battery working

was in suitably providing for extension line facilities. The circuit arrangements illustrated permitted only of the use of the central battery to supply current for direct exchange lines and for extension lines in parallel. No means were provided for supplying current from the central battery for working extension lines

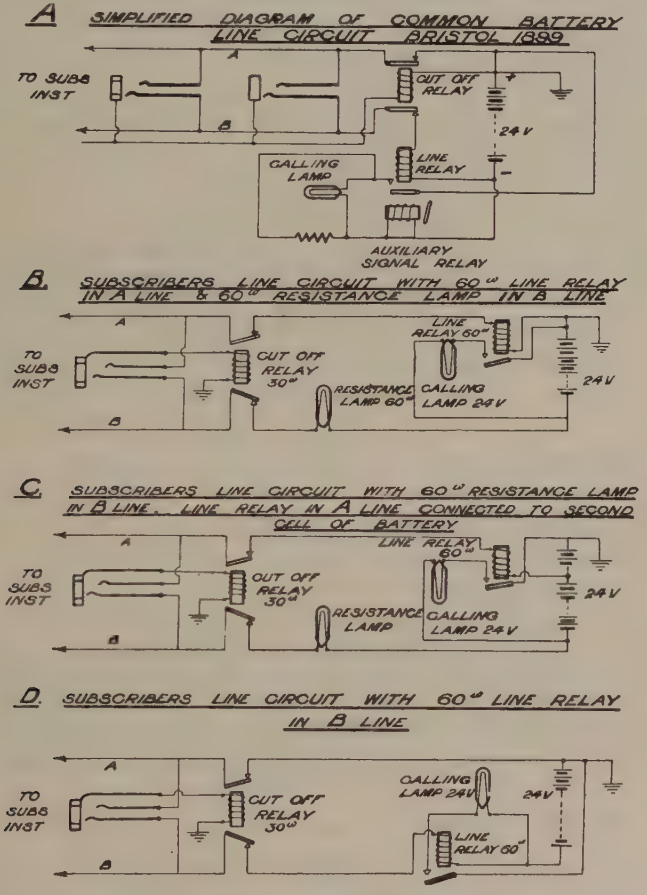
A SIMPLIFIED DIAGRAM OF COMMON BATTERY LINE CIRCUIT BRISTOL 1899
TO SUBS INST
A
B
CUT OFF RELAY
24 V
CALLING LAMP
LINE RELAY
AUXILIARY SIGNAL RELAY
B. SUBSCRIBERS LINE CIRCUIT WITH 60 ω LINE RELAY IN A LINE & 60 ω RESISTANCE LAMP IN B LINE
TO SUBS INST
CUT OFF RELAY 30 ω
LINE RELAY 60 ω
RESISTANCE LAMP 60 ω
CALLING LAMP 24 V
24 V
C. SUBSCRIBERS LINE CIRCUIT WITH 60 ω RESISTANCE LAMP IN B LINE. LINE RELAY IN A LINE CONNECTED TO SECOND CELL OF BATTERY
TO SUBS INST
CUT OFF RELAY 30 ω
LINE RELAY 60 ω
RESISTANCE LAMP
CALLING LAMP 24 V
24 V
D. SUBSCRIBERS LINE CIRCUIT WITH 60 ω LINE RELAY IN B LINE
TO SUBS INST
CUT OFF RELAY 30 ω
CALLING LAMP 24 V
24 V
LINE RELAY 60 ω

FIG. 131.—Simplified diagrams of Western Electric Company's Common Battery Line Circuits employed in the United Kingdom.

on private branch exchanges, consequently local batteries were still required in such cases and the purpose for which the common battery system was devised appeared therefore to be partially defeated. The Western Electric Company, however, soon produced an ingenious arrangement whereby battery current might

be drawn from the central battery, over the direct exchange line, for serving extension lines working in conjunction therewith; this could be done even when the direct line was in use for conversation through the public exchange, and without the slightest disturbance or overhearing. The arrangement was generally known as the "'B' line feed," owing to the use made of the "B" line, which was cleared of all signalling apparatus and a 60 ohm resistance lamp inserted at the exchange as a safeguard for the secondary cells.

Fig. 131(*b*) shows the subscriber's line circuit in simplified form as arranged for supplying energy from the central battery for working extension lines. It will be observed that the line relay has been transferred from the "B" side to the "A" side of the line and that a 60 ohm resistance lamp has been introduced in its place. This lamp denoted the appearance of an earth fault on the "B" line, and also served the purpose of preventing excessive drain on the central battery during the time such a fault or faults existed. During the period 1901 to 1904, the National Telephone Company's London exchanges at Kensington, London Wall and Holborn were equipped in this way.

Fig. 131(*c*) shows a further modification. This circuit differs from the one previously referred to (Fig. 131(*b*)), only in that the 60 ohm line relay is connected not directly to the earthed end of the battery, but two cells from the earthed end, *i.e.*, at a point four volts above earth potential. Both the (*a*) and the (*b*) line wires were thus normally maintained at a higher than earth potential, and an earth fault on the "A" wire would close the line relay and cause the calling lamp to glow; a similar fault on the "B" wire would be indicated by the glowing of the resistance lamp.

The following Metropolitan exchanges of the National Telephone Company, as well as a number of provincial exchanges, were fitted with the line circuit mentioned:—North (Barnsbury) Sydenham, Hop, East, Brixton, Paddington, Gerrard, and Hammersmith; they were constructed during the period 1904 to 1907.

The method of supplying current to private branch exchanges over the "B" line was employed by the National Telephone Company experimentally in a few cases, but the results obtained were not regarded as satisfactory, and the experiments were therefore discontinued.

Eventually, after the problem had been carefully investigated, it was decided that the system was not economical and therefore the policy adopted was to avoid the complications and disadvantages associated with the " B " line feed, and to provide current from primary or secondary cells situated at the subscribers' premises, or alternatively by means of a power line installed for the purpose from the central to the private branch exchange, over which energy for working the extension might be drawn from the central battery, whichever course proved to be more economical. This system was eventually adopted by the National Company universally throughout the country in 1902.

The Post Office employed the " B " line feed for private branch exchange working somewhat more extensively on circuits connected to some of the Department's earlier exchanges, but eventually it was abandoned, and private branch exchanges were dealt with after the manner explained above as adopted by the National Telephone Company. There are, however, still in existence a number of installations associated with some of the older Post Office exchanges of the " B " line feed type. Later, exchanges installed by the Post Office were not equipped for " B " line feeding.

The special provision represented in the two foregoing diagrams was therefore discarded by the National Telephone Company and the Post Office in this country, and also in America, and the circuit indicated in Fig. 131(*d*) was adopted as the standard. The 60w. resistance lamp was no longer necessary in so far as the supply of current over the " B " line for extension purposes was concerned, and its use for indicating faulty lines being limited, it was therefore not retained. It will be observed on comparing this diagram with the first diagram in the same figure that the arrangements are precisely similar and therefore that the initial arrangement again came into common use. London exchanges fitted with the latter type of circuit were : Dalston, Bromley, New Cross, Lee Green, Streatham and Walthamstow. They were installed during the period 1909 and 1910.

Circuit arrangements, differing somewhat from those pertaining to the common battery system, produced by the Western Electric Company, were in course of time devised by other parties, but with the single exception of the Kellogg system adopted for the Battersea (London) Exchange by the National Telephone Com-

pany, already referred to, they were not employed in this country and therefore will not receive mention.

When the British Insulated and Helsby Cables Co. and the Peel-Conner Telephone Works Co. commenced the design, construction and installation of common battery equipment for the British Post Office, certain distinctive features differing from the practice of the Western Electric Company were introduced, but for the most part they were of minor consequence, and, as matters of detail, reference to them here will be omitted. There were, however, attached to the system employed by these two firms some material differences in circuit arrangement which are referred to in Chapter XV.

CHAPTER XIV

MUNICIPAL TELEPHONES, 1900–1912

DURING the period 1890–1900 particular interest was evinced by municipal bodies in the question of municipalisation of certain public services. Contrary opinions were held as to the desirability of municipalities taking upon themselves the responsibilities which attached to the working of such undertakings. Water, gas, electric light and power, and tramway services all came under review. Numerous schemes associated with electric light and power, and tramways, received consideration, and various public authorities ultimately acquired undertakings which existed, or commenced themselves to instal and work plant for the purposes named.

Needless to say, the telephone question did not escape attention, and in 1893 a vigorous campaign was commenced against the alleged inefficiency of the telephone service and the shortcomings of the National Telephone Company, and Municipal authorities began an agitation which had for its object the acquirement by Municipalities of licences empowering them to establish and work telephone systems. The Corporation of Glasgow led the way in this agitation.

Moved at length by the agitation, the House of Commons decided on March 1st, 1895, that a Select Committee should be appointed to consider and report whether the provisions which had been made for the telephone service in local telephone areas was adequate, and whether it was expedient to supplement or improve the provision, either by granting licences to local authorities or otherwise. The Committee's report was, however, abortive.

In 1897, the Government decided to hold a local investigation in Glasgow. The hearing lasted eleven days, and Sheriff Andrew Jamieson, who presided as Royal Commissioner, issued his report on November 29th, 1897. The Postmaster-General, however, still

hesitated, and was evidently reluctant to grant the desired authority. The Municipal agitation continued and applications did not cease to be made for permission to institute telephone service in local areas in competition with the National Telephone Company, all of which were refused.

In view of the unabated agitation, the House of Commons arranged on May 9th, 1898, for another Select Committee to be appointed "to inquire and report whether the service is, or is calculated to become, of such general benefit as to justify its being undertaken by Municipal and other local authorities, regard being had to local finance; and if so, whether such local authorities should have power to undertake such service in the district of other local authorities outside the area of their jurisdiction, but comprised wholly or partially in the same telephone area, and what powers, duties and obligations ought to be conferred or imposed upon such local authorities."

The Committee's report was issued on August 9th, 1898, and was to the effect that general, immediate and effective competition by either the Post Office or the local authority was necessary and that a really efficient Post Office service afforded the best means for securing such competition.

The Postmaster-General, acting on the recommendation of the Committee, therefore expressed his willingness to grant telephone licences to Municipalities and also announced that the Post Office would establish a local telephone exchange system in London.

An Act of Parliament followed on August 9th, 1899. This Act authorised the Treasury to issue out of the Consolidated Fund sums not exceeding £2,000,000 as might be required by the Postmaster-General for the purpose of the Telegraph Acts, 1863 to 1897. It also made provision for public authorities licensed by the Postmaster-General to provide systems of telephonic communication and to defray the expenses thus incurred out of the Corporation funds. It precluded existing telephone companies from opening an exchange in an area in which they had not, before the passing of the Act, established an effective exchange. It also provided for intercommunication between competitive systems.

On September 26th, 1899, regulations were issued stipulating the conditions under which intercommunication between rival systems was to be given.

The foregoing briefly recapitulates the circumstances in which the Government was persuaded, apparently much against its will, to make the requisite legislative provision for the issue to Municipalities of licences to establish and work telephone systems. Further and fuller particulars of the events which preceded the entry of the several corporations into the telephone field are included in Chapter XXI.

There is little doubt that the reluctance of the Government to agree to a procedure which they believed in all sincerity was unsound and opposed to the public interest was evidenced in the delay which ensued in acceding to the desires of Municipalities to be empowered to dispense telephone service.

On March 1st, 1895, on the occasion referred to in Chapter XXI, when the motion to refer to a Parliamentary Committee the draft agreement for the purchase of the National Telephone Company's trunk line system was before Parliament, Mr. A. Morley, the Postmaster-General, in the course of his remarks said :—

" I come to the queston of Municipal licences, and I hope that Hon. Members will not think that in anything I may say I am indicating other than a strong belief in, and approval of, Municipal government generally. I am a strong believer in Municipal government and in the Municipal authorities dealing with matters which they can more effectually control than the Central Government. But I want to point out that there is a great distinction between telephone companies and gas and water companies. Gas and water are requisites for every inhabitant in a district, but the telephone cannot, and never will be, an advantage which can be enjoyed by large masses of the working classes (an Hon. Member : ' In America it is '). I do not think the Hon. Member is aware of the fact that in the large towns of America instead of the ten pounds paid in London, they pay forty or fifty pounds for the telephone. (An Hon. Member : ' It is a necessity.') It is not a necessity which can be enjoyed by the mass of the population. The telephone is in no way a Municipal requirement; but it is a National one. It is no more local in its circumstances than is at the present time the post or the telegraph. I do not think that anyone would say that the Municipalities should have local control of the Telegraph and Post Office services. The telephone service is becoming internationalised. We have already spoken from London with Marseilles, and before long there will be telephonic communication with every large town on the continent. That view of mine that the telephone service is not local but

National and Imperial has been confirmed in rather a striking way by that very Association of Municipal Corporations which has been quoted to-day as opposed to the policy of the Department. They passed a resolution in these words, 'That the subject should be treated as an Imperial and not as a local one.' I venture to think that the granting of Municipal licences would be in effect treating it as a local and not as an Imperial one. But of course I recognise and the Government recognise that the House of Commons takes great interest in this question as do the different localities. The Government is not disinclined that this question should be fairly and openly considered and therefore I am glad to be able to announce that we are prepared to assent to a Committee with the object of considering the question of Municipal licences and also the question of the advisability of competition that has been raised and upon which I have said very little this evening."

On June 15th, 1899, a paper was read before the Municipal Electrical Association on "The Municipalisation of the Telephone," in which the advantages of Municipal telephone control were set forth and the matter was generally discussed in favour of Municipalisation. Estimates of the capital cost of establishing telephone exchange service were given on a basis of £20 per subscriber's exchange line, and in the discussion which followed the views expressed in the paper generally were supported.

The Electrician, in a leading article published in its issue of June 30th, 1899, commented as follows upon the paper and the ensuing discussion :

"The assurance with which engineers whose experience in the design and working of large telephone exchanges is practically nil, expressed themselves ready to undertake the duties of Municipal telephone engineer was astounding." "If the present advocates of municipal telephony are representative of those to whom the management of it would be entrusted, the longer the country is spared this phase of municipal trading the better."

The estimate of £20 per subscriber was criticised and it was pointed out that two small municipal exchanges cited in the paper cost £33 and £45 per subscriber in a country where material and labour were cheaper than in this country.

Sir William Preece, who persistently stated his disagreement with the policy of instituting municipal telephones, on being asked by the Portsmouth Ratepayers' Association whether the

estimated figure of £19 10s. which had been prepared for Portsmouth was a reasonable figure for the construction of an exchange connection, provision of instruments, etc., to form a complete telephonic service, stated that in his opinion the telephone service should be in the hands of the Post Office, and that his estimates of 1895 were £55 per subscriber in London and £45 in the Provinces. His estimate for Portsmouth was £35 per subscriber, and he considered that £19 10s. could only represent something very cheap and nasty.

Apropos of the capital cost of telephone construction, it may be mentioned here that in the Postmaster-General's report for the year ended March 31st, 1906, it was stated that the average cost incurred by the Post Office per subscriber's exchange circuit, exclusive of spare plant, had been £35 13*s.* 10*d.*, as compared with £38 18*s.* 9*d.* for the previous year.

Out of a total of 1334 Municipal bodies, some 60 gave serious consideration to the question of establishing telephone systems competitive with the National Telephone Company. Many of them sought and secured technical advice. Excluding the States of Guernsey, the authorities for the following 13 towns applied for and eventually secured licences :

	Date licence granted.	Date licence expired.
Glasgow	March 1st, 1900.	December 31st, 1913.
Tunbridge Wells	May 30th, 1900.	April 30th, 1925.
Brighton	May 3rd, 1901.	April 30th, 1926.
Portsmouth	September 21st, 1901.	June 30th, 1926.
Hull	August 8th, 1902.	December 31st, 1911.
Swansea	September 27th, 1902.	December 31st, 1920.
Belfast	February 28th, 1901.	December 31st, 1911.
Chard	December 13th, 1901.	June 24th, 1922.
Grantham	September 18th, 1900.	December 31st, 1911.
Huddersfield	February 22nd, 1901.	February 28th, 1926.
West Hartlepool	September 30th, 1902.	September 30th, 1927.
Oldham	December 31st, 1902.	December 31st, 1920.
Scarborough	December 31st, 1902.	December 31st, 1911.

Of these 13 places, only the first 6 upon the list, namely, Glasgow, Tunbridge Wells, Brighton, Portsmouth, Hull and Swansea carried the matter through to a practical issue and actually inaugurated telephone service.

Mr. A. R. Bennett acted as consulting engineer to each of the 6 corporations mentioned.

It will be seen later that the larger exchanges for Glasgow were the first to receive attention, and that the call wire system was adopted. The most objectionable feature of the call wire system was the call wire itself, with all its attendant disadvantages. The advantages claimed for it were that secrecy was secured, that the introduction of complicated signalling apparatus into the speaking circuit was avoided and that subscribers were enabled to ring through one to another after connection had been established at the exchange without giving any signal thereat and by this latter feature the operator's time, in herself ringing the subscribers wanted, was saved.

From time to time numerous efforts have been made to dispense entirely with the call wire and the costs and disadvantages associated with it, but to retain as far as possible the advantages of the call wire system. Mr. Bennett himself attacked this problem and during the period 1890–1892 devised certain systems which he embodied in some of the exchanges to be referred to later. These systems had for their bases ideas contained in a series of patents taken out by Mr. Bennett in 1891 and 1892, the principal features of which were :—

(1) Metallic circuits were used exclusively for speech transmission.

(2) Calling was effected over one wire of the loop and the earth as return either automatically by movement of the switch lever when the receiver was removed, or by the subscriber depressing a special key mounted upon his instrument, which completed the earth connection at the subscriber's end, the signal being received upon an indicator connected to earth through a common signalling battery at the exchange.

(3) After the operator had completed the desired connection, the calling subscriber himself rang the distant subscriber by means of the magneto provided for the purpose (or alternatively the operator herself called him).

(4) The operator was unable to listen in on the circuit during the time the subscribers were connected.

(5) Clearing was effected either automatically by movement of the switch lever when the receiver was replaced, or by the subscriber again depressing the special key, when the earthed circuit was completed through a common battery and ring off indicators included in a special manner in the cord circuit.

Alternatively, the subscriber's requirements might be given to the operator, who was constantly listening, over a circuit formed by the depression of the subscriber's key.

For further information, the patent specifications enumerated below, covering these devices, should be referred to :

12484 of July 23rd, 1891.
18451 of October 27th, 1891.
19020 of November 4th, 1891.
20545 of November 26th, 1891, in the name of A. R. Bennett and R. McLean.
15238 of August 24th, 1892.
16124 of September 8th, 1892.
19834 of November 3rd, 1892.

Glasgow Municipal Telephone System, 1900–1906

The Glasgow Corporation was foremost amongst Muncipalities in the endeavour to secure authority for and to open up competitive telephone service, and was licensed by the Postmaster-General to serve telephonically an area approximately 140 square miles in extent, which included Clydebank, Govan, Partick, Kirkintilloch and Kilsyth.

Construction of the system was commenced in July 1900 and service opened with its Central Exchange on March 28th, 1901. Before August 29th of the same year, three other exchanges, viz., Exhibition, Hillhead and Bridgeton, were opened, the total number of subscribers served at that time being 1450. In order to attract subscribers at the outset, free service was rendered for a considerable period. The flat rates adopted by the Corporation were as below :—

£5 5*s.* 0*d.*, exclusive unlimited service.
£4 4*s.* 0*d.*, two-party line.
£3 3*s.* 0*d.*, four-party line.

Trunk communication was given on June 2nd, 1901.

The switchboards were manufactured and installed by the Telegraph Manufacturing Co., Ltd. The subscribers' instruments were supplied by the Ericcson Bell Telephone Company, and the General Electric Co., Ltd. Underground cables were supplied and laid by the British Insulated Wire Co., Ltd.

The accommodation at the largest exchange, viz., Central, situated at Castle Chambers, Renfield Street, was originally for 3000 subscribers, and facilities were stated to be available for extension to enable 10,000 lines to be accommodated.

The Central Exchange was ceremoniously opened on August 29th 1901, and afterwards the Right Honourable R. W. Hanbury, the Financial Secretary at the time, who was present at the opening ceremony, received the honour of the freedom of the city.

The call wire system was adopted for the Central, as also for four of the larger subsidiary exchanges, viz., Bridgeton, Kinning Park, Hillhead and Queen's Park. The switchboard multiple of these exchanges was "flat" or horizontal with operators accommodated on either side; the multiple field was thus common to operators situated opposite to one another, a practice at that time considered obsolete both by the Post Office and the National Telephone Company.

The plugs and cords, the indicators and listening and ringing keys associated with the junctions, and the order wire keys were accommodated in a canopy suspended from above. The general arrangement of the switchboard was, in fact, in many respects similar to that illustrated in Figs. 87 and 91.

A photograph of a portion of the Kinning Park Exchange switchboard, taken for the author by Mr. E. J. Johnson, of Glasgow, is reproduced in Fig. 101.

The development of the Glasgow Corporation telephone system is illustrated by the following figures which represent the number of telephone stations working in the year stated:

Year.	*No. of Stations.*
1902	5479
1903	9122
1904	11405
1905	12362
1906	12821

On September 15th, 1902, when the interest displayed in municipal telephony was at its height, Mr. J. E. Kingsbury, who for many years has been recognised as one of the greatest authorities on telephone questions, read a paper entitled "The Future of the Telephone in the United Kingdom," before Section

G of the British Association for the Advancement of Science at Belfast.

In this paper, Mr. Kingsbury devoted a good deal of attention to the question of competitive telephony, and advanced convincing arguments as to why telephonic competition was not only undesirable but wasteful, and therefore opposed to the public interest. Some of Mr. Kingsbury's statements were based upon the results which followed previous competitive enterprise and which, it is interesting to note, have since been repeated by more recent municipal telephone competition. He referred to some of the cases of competition which have been mentioned in this volume and gave concrete examples of the unnecessary capital expenditure arising from the duplication of plant inseparable from competition, and the dual subscriptions necessarily paid by those who desired communication with subscribers connected to rival systems not possessing facilities for intercommunication. Mention was made of the first case of competition which arose, namely, that between the Bell Company and the Edison Company in 1879, and the advantage of the increased capacity for communication which resulted from their amalgamation. The case of the Globe Company and the advantage in the reduction of telephone subscriptions which accrued from the cessation of a duplicate service was also referred to.

Mr. Kingsbury related how the Dundee and District Telephone Company, at the time of its acquisition by the National Telephone Company, had 332 subscribers, of whom 152 subscribed to the two systems, and he illustrated arithmetically the reduction in annual cost of the right to speak with other subscribers which occurred after amalgamation. Mention was also made of the later case of the Mutual Company of Manchester which, at the time of its absorption by the National Company, had 492 of its 1349 subscribers also connected to the rival system, and it was shown that the amalgamation resulted in a reduction of the cost of the opportunity to communicate by more than 50 per cent.

The "admirable arrangements made by the Postmaster-General in London, where every subscriber to the Post Office system is in communication with all the 40,000 subscribers to the previously existing system, so that duplicates are unnecessary, and no expenditure is wasted," was referred to and comparison was made between telephone, electric light and tramway systems.

Towards the end of the paper Mr. Kingsbury prophetically said:

"It seems to me that the result of the competition now in progress may be easily foretold. I venture the suggestion that competition by Municipalities was provided for under a misapprehension of the value of telephone exchange service, and a misconception of the results, direct or indirect, which might be expected. I venture further the suggestion that those Municipalities which have undertaken such competition have done so under a mistaken view of the benefits to be obtained and the cost of obtaining them. But I have too great a faith in public opinion to doubt that as the lessons are brought home, the result of existing competition will be the same as previous competition. Duality will give place to unity as the only reasonable method of conducting the work. Unfortunately, the disadvantages must be apparent and realised before they are regarded and probably much expenditure will be incurred before the mistake is recognised. In the meantime, the future progress in the practical use of the most beautiful and most useful application of science which the past century produced will be seriously impeded."

During the year ended December 31st, 1904, the Glasgow Corporation system increased by 1504 and the National Telephone Company's Glasgow system by 5209 stations.

One of the criticisms of the finance of the Glasgow Corporation undertaking was that insufficient allowance was made for depreciation. In the Glasgow Corporation telephone accounts for the third year's working a surplus of £3650 17*s.* 10½*d.* was declared, the total capital expenditure being returned at £320,782 12*s.* The 1·1 per cent. allowed for depreciation, even when sinking fund was provided for as well, was considered by experts to be inadequate for plant used for a telephone exchange system.

The policy followed by the Glasgow Corporation in adopting the call wire system of working in the year 1901, when the common battery system was available, was also criticised adversely. The chief reason why the call wire system was adopted in Glasgow appears to have been that as the National Telephone Company had for some years employed the same system extensively in Glasgow and also in other parts of Scotland, it was assumed that telephone users in the same locality, being accustomed to that method of working and having no experience of any other, would

prefer it. The call wire system was adopted apparently in deference to the wishes of the Telephone Committee.

After less than three years of call wire working, that is, in February 1904, the Glasgow Telephone Committee considered the question of abandoning the use of the call wire entirely, in favour of a system of direct signalling, and in January of the following year they recommended, and the Council decided, that the call wire system should be gradually superseded, and substituted by automatic calling and clearing by means of lamps.

On April 12th, 1904, Mr. A. R. Bennett read a paper entitled "Corporation Telephones" before the Glasgow Local Section of the Institution of Electrical Engineers, wherein the several Corporation telephone systems were described, Glasgow naturally being accorded the most attention.

There were present at the meeting both supporters and opponents of municipal telephony, and the discussion was somewhat animated.

Mr. Frank Gill, engineer-in-Chief to the National Telephone Company, concluded his remarks upon that occasion with the following somewhat prophetic utterance :—

"Those corporations which had embarked upon the telephone business did so at a date when much experiment and pioneer work, upon which vast sums had been expended, had been done. It was quite possible for them to enter into possession of knowledge and experience which had cost them nothing, but nevertheless one saw them to-day undergoing the experiences through which the telephone companies had passed years ago. The outcome was quite clear and unmistakable. In a short time—if indeed it was not already visible in the proposed abolition of the call wire in Glasgow—the system there and in the other cities mentioned must be reorganised upon a proper footing, and the infraction of what were now well known cardinal principles would reap its due reward in the very serious wastage which those cities would have to face."

In a report which accompanied the accounts of the Glasgow Telephone Department for the year ending May 31st, 1905, it was stated that the negotiations between the National Telephone Company and the Postmaster-General during the year which was past created a condition of doubt as to the future of municipal telephony, and had led to a diminution of activity in telephone work generally.

The end of the Glasgow Corporation venture came in 1906.

In March 1906 the Glasgow Corporation issued a memorandum setting forth the position of certain negotiations in progress with the Postmaster-General. It was stated that £360,000 had been expended upon the telephone system and that on the basis of the offers made to other Corporations (to be referred to shortly) the loss to the city incurred by sale to the Post Office would amount to £90,000. The opinion was expressed that the National Telephone Company would take over the system at its full capital value.

Under an agreement dated September 6th, 1906, as at June 1st, 1906, the undertaking was transferred to the Postmaster-General at a purchase price of £305,000, the Corporation having for some reason or other previously rejected a superior offer made by the National Telephone Company.

The Corporation originally claimed £322,000 and the value placed upon the undertaking by the Post Office was £266,087. The property was consequently revalued and on behalf of the Corporation the value was returned at £311,083.

The capital expenditure incurred in building the system was £380,000 and the difference between the purchase price (£305,000) and the total capital expenditure, amounting to £75,000, was made up by the sinking fund and a contribution from the city "Common Good" fund.

Approximately one-half of the subscribers' lines on the Corporation system were duplicated on the company's system which, at June 30th, 1906, comprised 27,356 stations.

The whole of the Municipal and National Company's telephone exchanges situated in the Glasgow telephone area at the time the Municipal undertaking passed into the hands of the Post Office are shown in Fig. 132.

The Municipal Central Exchange switchboard was replaced by a modern common battery switchboard, installed for the Post Office on August 13th, 1910. The activities of the Post Office and the National Telephone Company, who co-operated in the Glasgow area from 1906 to 1912, are briefly referred to in Chapter XV.

The last of the flat multiple call wire switchboards, originally installed by the Glasgow Corporation Telephone Department, to be thrown out of service, was that of the Kinning Park Ex-

change. This switchboard continued to give service until Saturday, February 11th, 1922. A photograph of the switchboard as it appeared immediately it had been rendered inoperative, for which the author is indebted to Mr. E. J. Johnson, is reproduced in Fig. 101.

Fig. 132.—National Telephone and Municipal Exchanges, Glasgow Telephone Area, 1906.

The transfer of the Glasgow Corporation telephone system to the Post Office was the occasion for much comment in the technical and public Press at the time, and gave rise to the expression of numerous views and arguments anent the financial situation. It was generally regarded by telephone engineers that the system had failed owing, first, to the modest estimate of £19 per working subscriber's line on which the system was established, secondly, to the inadequacy of the flat rate charge of £5 5*s*. for unlimited

service, and, thirdly, to the obsolete system and cheap form of switching plant adopted.

Tunbridge Wells Municipal Telephone System, 1901–1902

The telephone system of the Tunbridge Wells Corporation embraced an area of approximately 180 square miles, with Tunbridge Wells as centre, and therefore was not confined within the Municipal boundary; in fact, a distinctive feature of the Tunbridge Wells scheme was that it embraced a very large country area which was not under the jurisdiction of the Corporation. The towns and villages in this area were for the most part very small, many of them not possessing telephone facilities prior to their introduction by the enterprise of Tunbridge Wells. The scheme was an ambitious one and provided for the establishment of exchanges in no fewer than forty-eight places, excluding Tunbridge Wells itself. The system was officially inaugurated with some ceremony on July 29th, 1901, and by August of the same year there were over 500 subscribers connected.

The telephone rates adopted by the Tunbridge Wells Corporation were as follows :—

£5 17*s.* 6*d.*, unlimited service.
£3 10*s.* 0*d.*, and ½*d.* per originating call.
£2 10*s.* 0*d.*, ,, 1*d.* ,, ,, ,,

The National Telephone Company responded to the threatened competition and immediately lowered their rates to £4 per annum, a figure which included 5000 outward calls, 6*d.* being charged for each additional 100 calls.

The Corporation exchange at Tunbridge Wells, situated at 5 Calverley Parade, was provided with a switchboard supplied by the Telegraph Manufacturing Company, of Helsby, later known as the British Insulated and Helsby Cables, Ltd. The system was a magneto ring through system, and calling and clearing were accomplished by means of a central battery brought into circuit by the depression of a key by the subscriber. An advantage claimed for the system was that of secrecy, the operator being unable to hear conversations between subscribers. This feature was provided for by a socket contact which cut out the operator's telephone when the calling plug was lifted from the socket.

The subscribers' telephone instruments were manufactured by the General Electric Company.

The invariable practice adopted by telephone administrations up to this date was to provide a system of underground ducts or conduits, into which the necessary cables were afterwards drawn, a practice generally accepted by telephone engineers as best suited to meet the requirements of a telephone system. The underground plant associated with the Tunbridge Wells Municipal telephone system is, in this connection, of interest as the first case in this country so far as is known, where this policy was not followed; the dry core lead-covered cables used were protected by steel armour served with compounded tarred yarn and laid direct in the ground; they were manufactured and installed complete by Messrs. W. T. Henley's Telegraph Works Company.

The financial results of the working of the Glasgow and Tunbridge Wells systems, the two first Municipal telephone undertakings to be launched, were naturally watched closely by interested parties. Comments in the Press and elsewhere, criticising adversely the published accounts of those undertakings, no doubt had a steadying effect on the preparations which were in hand by other municipal bodies for the institution of local telephone service.

To the advocates of municipal telephony, some of whom were actively interesting themselves in local telephone schemes, an announcement that the National Telephone Company had been approached by a member of the Tunbridge Wells Council, relative to the disposal of their undertaking to the company, and that an agreement between the parties concerned had actually been drawn up to give effect to the transaction was, no doubt, not a little disturbing.

Learning of the proposed sale of the Tunbridge Wells undertaking to the National Telephone Company, and that the Postmaster-General was about to be approached for the purpose of securing his sanction to the proposal, an influential deputation of some of those chiefly interested in municipal telephony waited upon the Postmaster-General, Mr. Austen Chamberlain, on November 20th, 1902, to urge him to withhold his consent to the transfer, and to present their views upon the question of municipal telephone enterprise generally.

The Postmaster-General, after listening to the opinions expressed, replied to the effect that the most serious aspect of the question was the effect of the proposed sale upon the extension of the company's licence, which would transpire with the purchase of the undertaking, but that he would consider the whole matter and endeavour to give an answer in a few days.

On the following day, November 21st, 1902, the Postmaster-General received a deputation of Tunbridge Wells Town Councillors, headed by the Mayor, to discuss the proposed sale, and was asked to give his sanction to the agreement which had been prepared. It was alleged that the Corporation were misled, no doubt unintentionally, by their adviser, whose original estimate of the cost of construction per completed line was £17, afterwards increased to £21 15*s.* 6*d.* It had since been proved that not only had the cost been under-estimated, but that necessary work, representing capital expenditure to the extent of between £2000 and £3000, had been omitted. The actual cost per subscriber's line was £28 6*s.*, against the first estimate of £17. The whole of the loan on telephone account sanctioned by the Local Government Board was exhausted, and had produced 853 completed lines instead of 1148 as originally estimated. The deficiency of 295 lines at £28 6*s.* per line represented £8348, a most serious error on a total of only £25,000. The original estimate of revenue had also proved erroneous. The number of telephone subscribers in the Borough was 720 and, of the 436 living in Tunbridge Wells, no fewer than 150 subscribed to both the Corporation's and company's systems, so that really only 286 inhabitants of the Borough were actually dependent upon the Municipal system. The Council had no funds available for extensions of the telephone system, in fact they had not even the money to pay the wages of the labourers for that week, so that without a further loan it was impossible for the Corporation to carry on the undertaking. It was estimated that for the year which would end on March 31st, 1903, the loss on the Corporation telephone system would be £925, and that if the Borough were compelled to retain it, the inhabitants would suffer a loss of at least £1400 per annum, and more if outside subscribers were admitted. The proposed transfer to the National Telephone Company would ensure the ratepayers against loss, and at the same time give telephone facilities and advantages possessed by

scarcely any other town in the kingdom. If the Postmaster-General were disposed to take over the undertaking, on terms and conditions as advantageous to the ratepayers and telephone users as the National Telephone Company offered, the Council were ready to adopt that alternative.

The Postmaster-General stated that it was not his business to interfere, and explained the aspect of the question which more particularly concerned the Government. From the figures placed before him he did not think he could justify before Parliament the payment of such a price for the Municipal undertaking as the company had offered; he could not hold out any expectation of the Post Office paying £28,000 for what had only cost £25,000 in cash, and was not apparently even worth that sum. If the Tunbridge Wells Corporation had taken no licence, the licence of the National Telephone Company in that area would have expired in 1911, but the Borough authorities having obtained a licence, and Municipal competition being effectively started, the company became entitled, on fulfilling certain conditions (which had been fulfilled) to an extension of the period of their licence till 1925. If the competition, which was the consideration in respect of that extension of time, was to be withdrawn, it became matter for serious consideration whether the extension of the company's licence would be allowed. If not, then the Corporation and the company would have to reconsider the matter seriously in the light of that decision. He could not have regard to local interests only, but must exercise his judgment as to the much wider interests involved.

On the following day, Saturday, November 22nd, 1902, the Mayor of Tunbridge Wells was met by some of the supporters of the Municipal telephone movement, apparently much concerned at the trend of events, with a view to see whether there was not a possibility of finding a more graceful way out of the matter.

On Monday, November 24th, 1902, the Postmaster-General received yet a third deputation upon the same matter, this time consisting of members of the Tunbridge Wells local Ratepayers' League, who gave it as their view that the Corporation telephone system had proved a financial failure, that two separate undertakings with no intercommunication had proved a nuisance instead of an advantage, and had compelled over one-third of the Municipal subscribers in the Borough to join both systems, and

thus pay double subscriptions. The undertaking, besides showing a financial loss, had been discredited in the eyes of the ratepayers in other ways, and if the bargain with the National Telephone Company could not be concluded, a capital loss of £9000 would have to be met out of the general rate.

The Postmaster-General said, in effect, that the several deputations which had now waited upon him had placed him in possession of the views of all sections of the community at Tunbridge Wells, and of the points necessary to enable him to come to a conclusion on the subject, and his decision would be announced without any undue delay.

The Postmaster-General was subsequently advised by the Mayor of Tunbridge Wells of his discovery that the financial position of the Corporation was worse by more than £600 than was known to the members of the deputation on the previous Friday.

The principal terms of the proposed purchase embodied in the agreement which had been prepared were that the company would pay for the system the sum of £28,000, the charge for flat rate service was to be raised from £5 17*s.* 6*d.* to £6 and the message rate was to be subjected to an increase in rental of from £2 10*s.* to £3 10*s.* plus one penny instead of one halfpenny per originating call, with a minimum payment for calls of 30*s.* per annum.

The circumstances related regarding the position of the Tunbridge Wells telephone undertaking not unnaturally gave rise to considerable correspondence in the Press and numerous views were expressed. Mr. A. R. Bennett, the consulting engineer, found it necessary to point out that the cost of construction was not under-estimated, that the prices given for each class of work were ample and were actually worked to, but that the quantity was very greatly increased; that, broadly speaking, the extra expenditure entailed was due to departures from the original plan, the responsibility for which rested with the Council, and generally, that the circumstances which accounted for the over-expenditure were abnormal, and could not be laid to the charge of the estimating engineer. Mr. Bennett contended that the rates fixed were not too low under fair conditions, but that the Corporation enterprise was seriously handicapped by the cutting of rates by the National Telephone Company permitted by the

Post Office, and that the mischief had been done by extravagant working expenses.

As an indication of the views of a section of the ratepayers, it is interesting to note that the proposed disposal of the Corporation telephone undertaking was made the subject of a Municipal by-election at Tunbridge Wells, on November 29th, 1902, when the avowed opponent of the sale was defeated by 589 votes to 375.

In answer to a question in the House of Commons on December 11th, 1902, the Postmaster-General announced his decision regarding the proposal to transfer the Tunbridge Wells Corporation telephone system to the National Telephone Company, which was to the effect that he could not give his consent, except on certain conditions necessary to the maintenance of the policy approved by Parliament in the Telegraph Act of 1889. The company had already signified their preparedness to accept those conditions, which were that the Postmaster-General should retain the right to terminate the company's local licence on December 31st, 1911, and that the condition whereunder the Postmaster-General had the right to purchase such of the plant as might, on the expiration of the company's licence, be useful for Post Office purposes would be extended to the whole plant of the company existing in the Tunbridge Wells area in 1911.

At the time of the purchase of the Tunbridge Wells undertaking by the National Company, there were 853 subscribers connected to the Corporation system and 1015 to the National, and of these 180 subscribed to both.

Thus the Tunbridge Wells Municipal telephone venture had a very short existence, for in November 1902, as related, only 16 months after the service had been opened, the undertaking passed into the hands of the National Telephone Company. The financial interests of the Corporation in telephony thus came to an early termination. This was the first Municipal undertaking to be abandoned, and naturally the result was much commented upon at the time, and other Corporations which had already embarked upon similar schemes were given cause for thought as to their own financial position. It was generally accepted that the Tunbridge Wells failure was due to defective commercial organisation, and there is little doubt that the expenditure incurred in the attempt to develop telephonically a territory which was unlikely to prove remunerative, largely situated without the

Municipal boundary, contributed to the failure of the undertaking.

Shortly after the acquisition of the plant by the National Telephone Company, the Municipal switchboard, together with a large proportion of the outside plant, was scrapped, an indication of one at least of the disadvantages of dual telephone systems.

Brighton Municipal Telephone System, 1903–1906

Construction work associated with the Brighton Municipal telephone system was commenced in March 1903 and the service was opened on October 5th of the same year. As a consequence of a decision arrived at by the Corporation not to make any charge for the service until 750 subscribers had been connected—a somewhat risky experiment, perhaps, and one calculated to cause some concern to the National Telephone Company—the system only reached a commercial stage in March 1904, when the predetermined number of subscribers had been secured, and from which date charges for service were made.

The annual rental charges imposed by the Corporation were as below :—

£5 10*s.* 0*d.*, unlimited sevice.
£3 10*s.* 0*d.*, plus 1*d.* per originating call.
£4 4*s.* 0*d.*, two-party line.
£3 0*s.* 0*d.*, four-party line.

These rentals were apparently based on the consulting engineer's original estimate of the capital cost per working subscriber's circuit of £23 10*s.* Over 90 per cent. of the original subscribers elected to be charged on the unlimited rate basis.

The National Telephone Company introduced limited service rates, in addition to the flat rate of £10 per annum already in vogue (which was retained), as follows :—

£5 10*s.* 0*d.*, including 2500 calls per annum. } Additional calls
£5 0*s.* 0*d.*, ,, 1800 ,, ,, } ½*d.* each.
£3 10*s.* 0*d.*, two-party line.
1*d.* per originating call with a minimum of one call per day, ten-party line.
£1 5*s.* 0*d.* per annum and ½*d.* per call, twenty-party line.

The area of 120 square miles, in which the Brighton Corporation was licensed to give telephone service, extended along the coast line from Rottingdean to New Shoreham, and northwards as far as Burgess Hill, all of which places were included.

The exchange at Brighton was situated in a room of the old Pavilion. The switchboard, supplied by the Ericcson Bell Telephone Company, was equipped for 1000 lines and extension to 4500 lines capacity was possible. The subscribers' instruments were supplied by the same firm.

For calling the exchange, a central battery was brought into operation by a fleeting contact, made when the subscriber removed his receiver from the switch-hook, which momentarily earthed the "A" line. The battery and subscriber's indicator were cut out of circuit by insertion of the operator's answering plug and at the same time the subscriber's indicator was automatically restored. The operator called the subscriber whose attention was desired in the ordinary way by means of a ringing key.

There were two clearing indicators, one associated with the answering, and the other with the calling plug, the latter being utilised to indicate to the operator when the subscriber being called had answered. These two indicators were so wound as to permit the subscribers to ring through to one another by magneto, without calling the exchange; clearing was accomplished when the subscribers replaced their receivers, by operation of the same fleeting contact used in calling, which momentarily earthed the line at the subscriber's instrument and completed a circuit through the middle point of the clearing indicator winding and the earthed signalling battery at the exchange. The operator cleared only on receipt of the originating subscriber's clearing signal. The clearing indicators were automatically restored when the connecting cords were restored to normal.

Messrs. W. T. Henley's Telegraph Works Company were responsible for the laying of the Doulton conduit employed for accommodation of the underground dry core cables, and the latter were manufactured, laid and jointed by the British Insulated and Helsby Cables, Ltd.

The total capital expenditure to March 1906 was £52,718, and the number of subscribers' lines, approximately half of which were duplicated on the National Telephone Company's competing

system, was 1404, giving a capital expenditure per subscriber's direct exchange line working of £37 10s. The following figures illustrate the difference between the estimated and actual achievements :—

	Estimated.	*Actual.*
No. of subscribers' lines .	2080	1514
Capital expenditure . .	£43,280	£52,718

Early in October 1905 the disposal of the Brighton Corporation telephone system began to be talked of, the matter apparently being first raised by the Federation of Brighton Ratepayers' Associations. The Local Government Board, in dealing with applications from the Brighton and Swansea Corporations for loans for extension of their respective telephone systems, suggested that the Town Councils should consider the question of entering into negotiations with the Postmaster-General, with a view to the absorption of their undertakings by the Post Office. In answer to a question put at this time by Mr. John Burns in the House of Commons relative to the Municipal telephone undertakings, Lord Stanley, the Postmaster-General, stated that he was perfectly ready to enter into negotiations with any of the Municipalities that desired to do so.

In February 1906 the Postmaster-General offered to purchase the system for £41,200, a figure ultimately increased to £49,000, and accepted by the Brighton Corporation on July 26th, 1906, the transfer taking effect as from October 22nd, 1906.

The total capital expenditure on the undertaking was £56,147, and the net deficiency, after making certain allowances, was £3327. The "shuttlecock policy" of the Government was blamed for the alleged enforced sale.

Thus, after giving service for the short period of three years only, the Brighton Corporation was relieved of its telephone responsibilities, and was the third Corporation to relinquish its interest in the administration of telephone service.

Portsmouth Municipal Telephone System, 1902–1913

The telephone licence issued to the Portsmouth Corporation authorised operations over an area of about 100 square miles and, in addition to Portsmouth town and its environs, the towns of

Southsea, Gosport, Fareham, Cosham, Havant and other small places were included.

The rates adopted were as follow :—

£5 17*s.* 6*d.*, unlimited service.
£3 10*s.* 0*d.*, ,, ,, two-party line.
£5 0*s.* 0*d.*, including 1800 originating calls and calls in excess thereof at ½*d.* per call.
£3 10*s.* 0*d.*, and ½*d.* per originating call.
£2 10*s.* 0*d.*, and 1*d.* ,, ,,

Over 50 per cent. of the subscribers selected the first-mentioned rate.

The National Telephone Company was already well established in Portsmouth and modified its rates to the following :—

£10 0*s.* 0*d.*, unlimited service.
£5 10*s.* 0*d.*, including 2500 originating calls and calls in excess thereof ½*d.* per call.
£5 0*s.* 0*d.*, including 1800 originating calls and calls in excess thereof ½*d.* per call.
£3 10*s.* 0*d.*, plus ½*d.* per originating call.
£3 0*s.* 0*d.*, two-party line.
1*d.* per originating call with minimum of one call per day, ten-party line.
£1 5*s.* 0*d.*, including 600 calls. Omnibus service.

Construction work associated with the telephone undertaking of the Portsmouth Corporation was commenced in April 1902, and in March of 1903 an exchange was opened in the Town Hall with upwards of 700 subscribers. The switchboard was manufactured by the Telegraph Manufacturing Company, later the British Insulated and Helsby Cables, Ltd.

In some respects the system of working was similar to that arranged for Tunbridge Wells by Mr. A. R. Bennett, the consulting engineer. The subscriber called by depressing a key on his telephone instrument, earthing one line through a central signalling battery and a grid indicator. Insertion of an answering plug into the home jack disconnected the battery and restored the calling indicator. The engaged test was made by means of a test-thimble. On the calling plug being lifted from its socket the

clearing indicator was brought in circuit in place of the operator's telephone, which was cut out. The centre point of the clearing indicator was connected to earth through the signalling battery. On cessation of conversation, subscribers were expected again to depress the signalling key, which action caused the clearing indicator to operate. Subscribers' instruments included a magneto generator to enable them to ring through one to another, which was done without calling the exchange.

A general view of the switch-room is given in Fig. 133.

The subscribers' instruments were manufactured and supplied by the Ericcson Bell Telephone Company.

The requisite underground cables were protected by 3 inch cast iron pipes, and the installation of the whole of the underground system, including pipes, manholes and cables, was carried out by the British Insulated and Helsby Cables, Ltd.

During the year ended December 31st, 1904, the Portsmouth Corporation telephone system increased by 553 and the National Telephone Company's system in Portsmouth by 981 lines.

The Portsmouth Municipal telephone undertaking passed into the hands of the State on October 1st, 1913, a little under two years after the National Telephone Company's system, and thirteen years before the expiration of the period for which it was licensed to carry on telephone service.

At the time of its acquisition by the Post Office, the Portsmouth Municipal telephone system comprised eleven exchanges, viz., Portsmouth Central, North End, and Eastney, Fareham, Havant, Cosham, Gosport, Waterlooville, Rowlands Castle, Drayton and Evesworth, which gave service to subscribers numbering close upon 3000. During 1916, all the Municipal exchanges were closed down, the subscribers connected to them being diverted to Post Office exchanges already existing and serving the same territory as the Municipal exchanges. The subscribers working to the Central, Eastney and North End exchanges of Portsmouth respectively numbered 1347, 124 and 44, and were transferred to the new Portsmouth Automatic Exchange, opened by the Post Office on April 29th, 1916.

The Municipal exchanges were afterwards dismantled and the discarded plant was disposed of.

FIG. 133.—Portsmouth Corporation Telephone Exchange Switchroom.
(From a photograph supplied by Mr. J. S. Brown.)

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Hull Municipal Telephone System, 1904 to Present Date

The Municipal telephone undertaking in Hull has the distinction of being attended with more success than other Municipal telephone enterprises and is the only one of the six which actually instituted telephone service surviving at the present day.

The question of the establishment of a Municipal telephone system for Hull was first considered by the City Council in 1899, and after being petitioned by a large number of business people, the Corporation was successful in securing a licence on August 8th, 1902.

Before arranging for the construction of a system of their own, the Corporation approached the National Telephone Company with a view to acquire by purchase the system of that company but, as the price required was considered too high, the question of purchase was definitely abandoned, and the Corporation set about the establishment of a system of their own. The Local Government Board sanctioned a loan of £43,202 for the purpose, the work of construction was taken in hand in January 1904 and was completed before the end of the year.

The switching system originally adopted was known as "Bennett's Ring Through," but the switchboard was modified in 1908 and the system converted to admit of lamp working.

The licence was due to expire on December 31st, 1911; some five years before this date the Telephone Committee became much concerned at the prospect of the licence not being extended, and recommended to the City Council that the undertaking should be sold to the National Telephone Company. This suggestion did not mature, however, and upon application being made to the Postmaster-General, the licence was extended up to December 31st, 1932, conditionally upon the Hull Corporation purchasing the plant recently acquired by the Postmaster-General from the National Telephone Company, at the price paid for it, viz., £192,423. To this proposition the City Council agreed at a special meeting held on January 5th, 1914, by 42 votes to 12, and the plant recently acquired by the Post Office from the National Telephone Company was therefore added to that of the Municipal system. The transfer took place on May 6th, 1914, but was to date from January 1st, 1912. The Local Government Board sanctioned the necessary loan.

Some time ago a decision was arrived at that future extensions of the switching equipment should be made by the installation of automatic apparatus, and as a first step towards the establishment of machine switching a new automatic exchange of the Western Electric Company's rotary type was officially opened on February 6th, 1922. This exchange, which serves one of the suburbs of the city, was equipped for 1000 lines and gave relief to the Central Exchange. By the end of 1923, 900 subscribers were accommodated by the new exchange, and early extension of the equipment is now contemplated. Another automatic exchange to serve the outlying village of Sutton was opened towards the end of October 1923. It originally gave service to approximately 65 subscribers. Consideration is now being given to the provision of an automatic exchange centrally situated for giving service to city subscribers.

The following are the annual profits of the undertaking for each year since its commencement, after paying all working expenses, royalty and interest and sinking fund charges on loans.

Prior to acquisition of the National Telephone Company's system :—

Year ended March 31st.	*Profit.*	*Year ended March 31st.*	*Profit.*
1906	£476	1911	£1168
1907	1388	1912	1684
1908	1055	1913	1971
1909	1040	1914	2284
1910	1170		

Subsequent to acquisition of the National Telephone Company's system :—

Year ended March 31st.	*Profit or loss.*	*Year ended March 31st.*	*Profit or loss.*
1915	£5389 profit.	1920	£611 loss.
1916	3645 ,,	1921	13279 ,,
1917	5355 ,,	1922	3938 profit.
1918	6850 ,,	1923	14296 ,,
1919	1105 loss.		

As at March 31st, 1923, the following plant statistics were announced :—

Conduits	110 miles.
Mileage of underground wire	34,448 ,,
,, of overhead cable wire	424 ,,
,, of open wire	5,879 ,,
No. of poles	4,038
No. of telephone stations	13,872

In July 1919, consequent upon increased expenditure arising out of the war, the Corporation Telephones Committee decided to impose certain increases in rental.

The present rates now are :—

Tariff No. 1. An annual payment of £12 6*s.* 8*d.*, to cover an unlimited number of calls.

,, No. 2. An annual payment of £8 3*s.* 4*d.* for private houses, to cover an unlimited number of calls.

., No. 3. A two-party line for business premises at £9 3*s.* 4*d.* per annum; unlimited service.

,, No. 4. A two-party line for private houses, £7 per annum; unlimited service.

,, No. 5. A five-party line, with a minimum payment of £5 6*s.* 8*d.* per annum (payable quarterly), covering 720 calls. Extra calls at the rate of 10*s.* 8*d.* per hundred.

,, No. 6. Exclusive line, measured service, £7 to cover 500 calls. Extra calls at the rate of 6*s.* 8*d.* per hundred.

,, No. 7. Twenty-party line, £3 4*s.* 0*d.* per annum. Calls 6*s.* 8*d.* per hundred.

All rentals are payable in advance, and all inward calls are free. Extension line rates are according to distance.

The author is indebted to Mr. T. Holme, manager and engineer of the Hull Corporation Telephone Department, for much of the foregoing information.

Swansea Municipal Telephone System, 1903–1907

Swansea opened its Municipal telephone service on November 5th, 1903. The ring through system of working, locally known as " Bennett's Special," was adopted and the switchboard was designed for 750 lines. By February 1904 there were 566 sub-

scribers connected. During the year ending December 31st, 1904, the Swansea Corporation system increased by 488, and the National Telephone Company's competitive system by 702 stations.

Early in 1906 overtures were made by the Government for purchase of the Swansea Corporation system and £17,000 was offered for it. At a meeting of the Swansea Corporation, held on March 21st, 1906, the offer of the Postmaster-General was described as ridiculous, in view of the fact that the capital expenditure incurred amounted to £26,961 9*s.* 6*d.* In a letter from the Postmaster-General which was before the meeting it was stated, apparently in anticipation that the figure offered would be considered inadequate, that deductions must be made for depreciation. Eventually the Postmaster-General's offer was increased to £22,000, an amount still unacceptable to the Corporation.

Negotiations with the National Telephone Company were therefore entered into, and eventually were concluded in February 1907, when the system passed into the hands of the company for the full amount of the capital expenditure, viz., £28,700. It was reported at that time that the Swansea Corporation system comprised 1215 subscribers' lines, and 1465 instruments and lines working, and that 168 orders were in hand.

The Swansea system was designed on an estimated capital cost of £20 per line.

From 1901 to 1905 may be regarded then as the period of competition between the National Telephone Company and the Post Office and Municipalities. In 1900 the Post Office had not commenced actively to engage in the telephone business, and there were no Corporation systems in operation. The development which occurred in Great Britain and Ireland in this period is indicated in the following figures :—

	No. of Telephone Stations.	
	Jan. 1st, 1901.	Jan. 1st, 1905.
National Telephone Company	200,200	362,400
Post Office and Corporations	2,500	62,400
Total	202,700	424,800

Judged by the results, the Municipal experiments in the domain of commercial telephony were not voted a success. The Tunbridge Wells system passed into the hands of the National Telephone Company in less than two years after it commenced to give service. Brighton and Glasgow were transferred to the Post Office in 1906, and Swansea was acquired by the National Telephone Company in the following year. Of the two remaining systems, Portsmouth survived but a year after the National Telephone Company's system passed to State control and Hull alone has continued to the present date.

Failure of the Tunbridge Wells Municipal undertaking caused a good deal of comment at the time, and some consternation was no doubt felt by other Municipalities engaged in telephone enterprise and they were given cause to inquire into their own financial position.

The causes of failure were perhaps manifold. The policy adopted by the Corporations in attempting to establish telephone systems on such moderate estimates as were accepted and at such low flat rate rentals as were imposed was severely criticised and the wisdom of instituting systems of working considered by many competent engineers to be out of date was also questioned.

The common battery system had been developed, although not fully, in America, and was brought into commercial use there in 1896. It was introduced into this country in 1900 and was soon acclaimed a success. Within a year or two it was recognised that the common battery system had come to stay, and it began to be generally regarded as the accepted successor to the magneto system which at that time provided for the telephone requirements of the greater part of this country.

The call wire and the ring through systems adopted by the Corporations possessed certain advantages in that complex signalling arrangements were avoided, but the disadvantages were such that they could not compete with the common battery system and were regarded by experienced engineers as obsolete even at the time they were installed. It is significant that the need arose for the Glasgow Municipal Central Exchange to be replaced long before the period of the life of an average exchange had elapsed, and it was scrapped in 1910, less than ten years after the opening date. The National Telephone Company's system

in Glasgow, in operation for many years prior to the inauguration of the Corporation system, included five up-to-date common battery exchanges when handed over to the Post Office in January 1912.

As public authorities, the Corporations possessed many advantages over the National Telephone Company, and it is reasonable to suppose that ratepayers would be fain to view the Corporation enterprise with more favour than that of a private company, but the National Company was financially powerful, its organisation was strong, it was served by a large and experienced staff and it was accustomed to meet with opposition.

There appears to be little doubt that the Company's superior position in these respects contributed to the want of success which attended the efforts of those Municipalities which failed.

States of Guernsey Telephone System, 1896 to Present Date

The telephone system of the States of Guernsey cannot perhaps be correctly termed a Municipal system, yet the enterprise is not dissimilar from those embarked upon by the Municipalities mentioned both as regards ownership and management. Moreover, the movement responsible for its institution took place within the period in which some of the Corporations agitated for licences empowering them to administer telephone service, and it will therefore be appropriate to refer to the Guernsey system in the present chapter.

The island of Guernsey, the second largest of the Channel Islands, has an approximate area of 23·5 square miles and in 1896 there was no public telephone service, although the National Telephone Company had made an attempt to establish a system. With the exception of St. Peter Port, the capital of the island, a port equipped with an excellent harbour from which the produce of the island is wholly shipped, there are no populous settlements; by nature of its occupation the remainder of the population is scattered over the island and in 1896, in the interests of the community, telephone service was considered to be essential.

The National Telephone Company was prepared to establish a telephone system in Guernsey, but Major-General Mainguy, R.E., a resident of the island, with experience of the telephone system in Switzerland, where he at one time resided, pronounced that the

tariffs proposed by that company were excessive. As a consequence, Mr. A. R. Bennett was invited to visit the island and tender his expert advice.

A public meeting was convened for March 4th, 1896, at St. Peter Port, and another at St. Sampson's on the following evening, when Mr. Bennett laid before the assembled residents his views and proposals. A representative of the National Telephone Company was present and announced his company's terms, which were rejected as being too onerous.

At both meetings resolutions were passed requesting the State to undertake the telephoning of the island. Application for the necessary licence was made immediately to the Postmaster-General, who did not view the proposal favourably, and Major von Donop and two Post Office officials were commissioned to visit the island and furnish a report upon the proposal. The gist of the report was that the tariffs proposed to be charged by the States were insufficient to support a financially sound and efficient telephone system, and the licence was therefore withheld. The National Telephone Company took the opportunity to offer more favourable terms, but by this time the Guernsey people had become interested in the idea, and were determined to establish and work their own telephone system if at all possible.

Eventually, after the intervention of Mr. Henniker Heaton, a licence was granted in May 1897, and general satisfaction was expressed. The work of construction of the system was immediately taken in hand, and the exchange at St. Peter Port was opened on June 28th, 1898, with 217 subscribers.

The method of working adopted was the "Bennett Ring Through System," similar to that subsequently applied in several of the Municipal telephone undertakings. The original switchboard provided accommodation for 300 subscribers and the lines were metallic circuits throughout.

The practical support accorded the undertaking was evidenced by the development, and on October 3rd, 1905, a new multiple switchboard, installed at a cost of £2,700, was brought into service. The fitted capacity of this board was for 900 and its ultimate for 3100 lines. There were originally nine operators' positions for subscribers' lines, one for public call office circuits, which formed an outstanding feature of the service, and one for junction working, making eleven operators' positions in all. The

ring through system was retained, calling being accomplished by means of magneto, also used for ringing through to the distant subscriber after completion of a connection by the operator.

The clearing signal was operated by depression of a key, fitted on the subscriber's instrument, which completed a circuit through the "A" line, earth, clearing indicator and a common battery accommodated at the exchange. There were two ring off indicators, one in each side of the double cord circuit, and the operators acted under instructions to clear a connection only on receipt of the dual signal.

A feature claimed for the Guernsey system was that of secrecy; any attempt made by the operator to connect her instrument in circuit by the normal means was accompanied by disconnection of the two subscribers who were conversing.

The switchboard was manufactured by the International Electric Company of 55 Redcross Street, London, E.C., and was installed under the supervision of the late Mr. Robert McLean, then resident engineer and manager.

No telephone communication beyond the confines of the island existed until 1915, when communication was established with the island of Sark, situated some nine miles east of St. Peter Port, by means of a single conductor submarine cable laid for war purposes by the British Post Office, and opened for public use on May 1st, 1915.

The Guernsey States Telephone Department take to themselves the credit of having developed telephonically the island of Guernsey to the extent that it is now by far the best telephoned area in the British Empire.

As at December 31st, 1921, when the number of direct exchange lines was 2393 and the population 37,914, the number of inhabitants per direct line was 15·8, and if telephone stations be taken as a basis the number of inhabitants per station was 13·6.

Visitors to the island brought into touch with the telephone service have been impressed with the popularity the telephone enjoys. A telephone instrument may be found even in small cottages, the low charges bringing the service within reach of even the very modest tradesman and householder.

A schedule of the tariffs charged is appended:

	1898.	Novr. 1900.	Aug. 1920.
Tariff A.	£1 10*s.* per annum plus 1*d.* per call.	£1 10*s.* per annum plus 1*d.* per call.	Private Houses £2 10*s.* per annum with 120 free calls. Afterwards 1*d.* per call. Business premises £3 per annum with 240 free calls. Afterwards 1*d.* per call.
Tariff B.	£2 10*s.* per annum plus ½*d.* per call.	£2 5*s.* per annum plus ½*d.* per call.	£3 10*s.* per annum plus ½*d.* per call.
Tariff C.	£5 13*s.* 4*d.* per annum including 3200 calls.	£5 per annum including 3200 calls.	£6 10*s.* per annum including 3200 calls.

Some particulars indicative of the progress of the States of Guernsey telephone undertaking are given in Table No. 12.

For much of the foregoing information the author is indebted to Mr. Ernest H. Bennett, the present resident engineer and manager of the States of Guernsey Telephone Department.

CHAPTER XV

THE POST OFFICE IN LONDON AND THE PROVINCES, 1899–1912

THE Post Office telephone exchange system dates back from the time when telephone instruments began to replace the Wheatstone A B C telegraph sets connected to certain switching devices referred to in Chapter V. With the exception of Newcastle and Cardiff, the Post Office did not attempt to enter vigorously into competition with other telephone administrations. As mentioned, however, in the section devoted to "Municipal Telephones," on the recommendation of a Select Committee of the House of Commons, the Postmaster-General in 1899 offered to grant telephone licences to Municipalities who desired to establish telephone exchange service and, in addition, announced that the Post Office would establish a local exchange system in London.

Immediately prior to this decision being acted upon, that is in the year 1901, apart from the trunk lines of communication, the Post Office telephone system comprised but a small portion of the system of the United Kingdom. In all, it gave service, in January 1901, to 2026 exchange lines. Many of these were call offices and exchange lines provided for private firms exclusively for trunk service or transmission by telephone of telegrams to or from the Post Office. This number of lines was served by 112 exchanges scattered throughout the country. Most of them were very small, and many could not, in the strict sense of the term, rank as exchanges, as they had connected to them only one or two lines, either call offices or lines provided for the particular purposes which have been mentioned. Twenty-five of the 112 exchanges referred to had only one line connected, sixteen had two lines, twelve three lines and five four lines. The largest exchange was Newcastle-on-Tyne with 650 direct exchange lines and the second largest Cardiff with 226 lines, while Newport followed third with 114. In the whole of London

the sum total of the exchange lines of all classes served by the Post Office was 117.

The following statement shows broadly the distribution of subscribers throughout the country connected to the Post Office telephone exchange system :—

London . . .	117	
Ireland . . .	15	
South Wales . .	726	including Cardiff with 226 and Newport (Mon.) with 114.
Scotland . . .	10	
North of England .	900	including Newcastle-on-Tyne with 650.
Remainder of United Kingdom . .	258	
Total . .	2026	

The Telegraph Act of August 9th, 1899, precluded the National Telephone Co., Ltd., from opening an exchange in an area in which they had not, before the passing of the Act, established an effective exchange. Upon the passing of this Act the Post Office entered into preparations for the establishment of telephone service in such areas, and to compete with the National Telephone Company in London.

The agreement entered into between the Postmaster-General and the National Telephone Co., Ltd., on November 18th, 1901, for the purchase of the plant owned and worked by the company in the London Exchange area, on the termination of the company's licence, provided for co-operation in London between the Post Office and the company during the remaining term of the licence.

The Metropolitan area embraced about 640 square miles of territory; it was divided into three distinct portions wherein respectively the development of the local telephone service was to be carried on.

(*a*) By the National Telephone Co., Ltd., alone (commonly known as Yellow area).

(*b*) Exclusively by the Post Office (commonly known as Green area).

(*c*) Jointly by the Post Office and the company in competition (commonly known as White area).

The existing exchanges in the territory to be developed wholly by the Post Office were to continue under the jurisdiction of the company, who were to refrain from carrying out any new

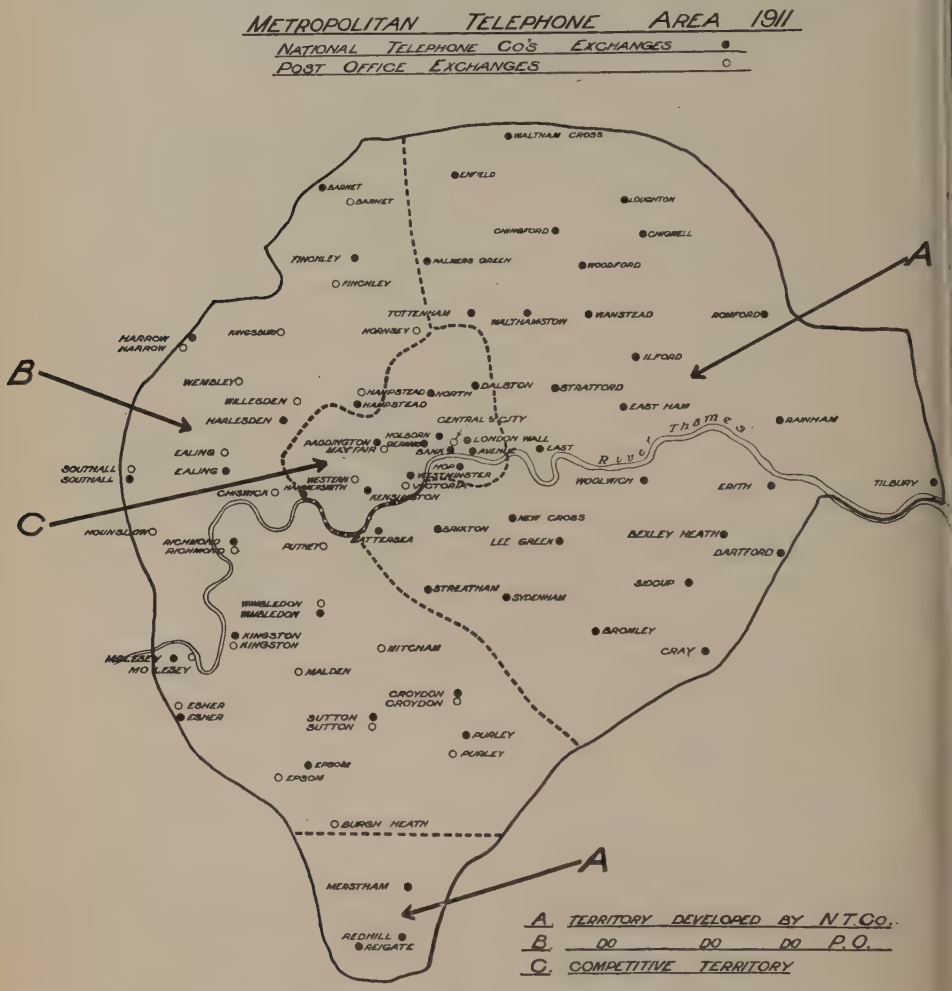

FIG. 134.—National Telephone and Post Office exchanges in the Metropolitan Area, 1911. Allocation of Territory to the two administrations.

work of construction, unless by arrangement with the Post Office, except that essential for maintenance of the existing plant, the Post Office reserving to itself responsibility for the provision of plant necessary for future telephone requirements of the territory in question. Broadly, the National Telephone

Company were to develop as necessary the Eastern half of the Metropolitan area and the Post Office the Western half, while competition was to be freely permitted in the City, Centre, and West End. These three areas are shown geographically in Fig. 134. This arrangement reduced the tendency to duplication of plant, which would undoubtedly have occurred had development by both parties continued without discrimination.

In the provinces the requirements of all the towns of consequence were already provided for by exchanges operated by the company, and provision had been made by Act of Parliament for those Municipalities which desired to do so to enter into competition with the National Telephone Company. The operations of the Post Office were, therefore, largely confined to opening up service in rural areas and sparsely populated localities disregarded by the National Telephone Company.

The telephone services instituted by the several Municipalities can be correctly termed competitive, inasmuch as they were permitted to arrange their own rates, and the company was in a position to retaliate more or less as its policy dictated, but with the Post Office and the National Telephone Company in London the case was different, inasmuch as the two administrations really acted in co-operation; the agreement entered into between the two parties on November 18th, 1901, provided for the same rates being charged and for free intercommunication between the two systems. In this sense, the two administrations cannot be regarded as entering into serious competition one with another, and competition took place, therefore, only in regard to the quality of service rendered and of expedition in providing new subscribers with the telephone connections they desired.

The prospective undertaking of the Post Office in London was at this time one of considerable magnitude and one which presented no small difficulty in its accomplishment. The Post Office engineering staff was sufficient only for the needs of the engineering work undertaken at the time by the Department, and a specialised telephone staff had therefore to be gathered together. The experience in telephone work of the greater portion of the Post Office staff was at the time limited to that afforded by administration of the trunk service worked by the Post Office since its acquisition in 1896 only, and to the small local

services mentioned. The Post Office possessed one great advantage denied to the National Company, viz., a practically free hand in so far as rights of wayleave were concerned in the provision of underground work, and this served the Post Office in good stead, for from the first the line system was wholly underground within the Metropolis, and largely so in the suburbs, whereas the company's line system in London was, unfortunately, for the most part overhead, a severe handicap not easily remedied. The powers possessed by the Post Office in regard to the erection of overhead lines in public thoroughfares were largely taken advantage of in suburban districts.

Construction work for the Post Office London telephone system commenced in May 1900, and in spite of the many and varied difficulties, which cannot be enlarged upon here, progress was such that the first Post Office exchange in London was opened on March 1st, 1902. The name by which the exchange was to be known was " Central." It was situated in the Savings Bank Buildings, Queen Victoria Street.

Unlike the inexperienced Municipalities who ventured into the telephone business, the Post Office wisely adopted the most up-to-date and approved system of working, viz., the Western Electric Company's common battery system, adopted for the first time in Europe by the National Telephone Company at Bristol in 1900. The Western Electric Company supplied and erected the equipment, which was of their standard type. The system has been so extensively used and is so well known that detailed description is here unnecessary. Particulars of the equipment installed at the London Central Exchange, which was similar to that of numerous other Western Electric common battery exchanges opened in this country from time to time, were given in the technical Press at the time the exchange was opened, and an illustrated account of the installation is contained in a book issued in 1904 by *The Electrician* Printing and Publishing Co., Ltd., entitled, " The Post Office Telephone Service."

A general account of the introduction and development of the common battery system in the United Kingdom, with the salient technical features thereof, will be found in Chapter XIII.

The ultimate capacity of the Post Office Central Exchange was stated to be for 14,400 subscribers' lines and 1800 outgoing

junctions; its initial fitted capacity was for 5400 subscribers and 240 outgoing junctions. The local board consisted of 10 nine-panel three-position sections each containing a complete multiple. The junction board was multipled similarly to the local board and consisted of three nine-panel three-position sections. The outgoing junctions were multipled every six panels.

The line plant associated with the Post Office Central Exchange, as well as other exchanges subsequently opened in the heart of London, was wholly underground, and its installation constituted a work of great magnitude and capital outlay. It was described in numerous technical journals when the plant was under construction, and brief mention of some of its important features will be found in Chapter XIX.

Two additional exchanges were opened by the Post Office in London in 1902, one termed "Western," situated in two private houses, 126–128 Cromwell Road, South Kensington, and the other at the South-Western District Post Office, Westminster, with the Royal title "Victoria." Both these exchanges were similar in type to the Central Exchange although of less capacity, Victoria providing an ultimate capacity of 5400 subscribers and being initially fitted with a multiple for 1000 lines.

In November 1907 the Post Office Hornsey Exchange was opened. It was situated in the Broadway, Crouch End, and was opened with approximately 200 subscribers. The equipment, which was contracted for by the Western Electric Company, was of common battery type and had a fitted capacity for 2700 subscribers and an ultimate of 5400.

The development of subscribers working to the Post Office London Central Exchange which, considering the telephone density of London, served a very large area, was rapid. The exchange was opened on March 1st, 1902, with approximately 200 subscribers. In three years this figure had grown to close upon 10,000, and by 1908 the full capacity of the exchange had been exhausted. It soon became apparent therefore that early provision of additional switching equipment, for relief of the Central Exchange switchboard, would be necessary, and it was decided to equip a second exchange in the same building, to be known as "City." It was anticipated that this second exchange would accommodate as many as 16,000 subscribers, making a total of 30,400 lines in the same building.

Although the number of subscribers to the Central Exchange was so large, it was found that the percentage of junction working was high, over 80 per cent. of the originating calls being for subscribers connected to other exchanges. For one only, therefore, out of every five calls was the subscribers' multiple made use of, all the others passing over the junction lines. The use made of the subscribers' multiple of the Central board was therefore comparatively small, and the experience thus gained was made use of in arriving at a decision as to the methods which should be adopted in handling the calls at the new City Exchange. It was arranged entirely to dispense with the subscribers' multiple on the answering positions and to deal with every originating call as a junction call. The multiple on the "A," or answering, operators' positions was, therefore, reduced to that necessary only for outgoing junction lines to other exchanges; "B" positions in the same room were fitted with a full City multiple, at which calls confined to the City Exchange, as well as incoming calls from distant exchanges, were completed.

In other respects the equipment for the City Exchange was similar to that for Central, except that numerous improvements of a comparatively minor character, introduced since the latter exchange equipment was designed, were embodied.

The City Exchange was opened for service in November 1907; on January 1st, 1908, it gave accommodation to 121 subscribers' lines and by January 1st, 1912, these had increased to 4635, in addition to the 13,849 connected to Central.

In October 1910 a new Post Office Exchange was opened in London which, although not large, possessed several features of more than usual interest. It was situated in Willesden and was accommodated in a building erected specially for the purpose. It was the first London common battery exchange to adopt a working voltage of 40 volts, instead of the customary 24. It was installed by the Peel Conner Telephone Works, Ltd., the contractors to the Post Office, and employed, with slight modifications, the new circuit introduced by that firm at the Glasgow Central Exchange (referred to shortly), erected for the Post Office and brought into use on August 13th, 1910.

The Peel Conner Company acquired from the General Electric Company the exchange telephone manufacturing branch of their business and the Peel Works at Salford.

The Willesden Exchange was originally equipped for 2700 lines and had an ultimate capacity of 8100. There were 208 incoming junctions, 240 outgoing junctions and 40 incoming order wires. The subscribers' board consisted of six eight-panel sections multipled over nine panels and there were the usual three operators' positions per section. The junction board was fitted with nine-panel sections with a corresponding multiple. Generally the equipment was precisely similar to the board to be referred to later in this chapter fitted at Glasgow by the same firm.

The new Avenue Exchange of the Post Office is of particular interest from several points of view. Its construction was put in hand in such time prior to the date for transfer of the National Telephone Company's undertaking, January 1st, 1912, as was calculated to admit of its being brought into service simultaneously with the general transfer of the company's system, in consideration of the views held by the Post Office that the company's Avenue Exchange was unsuitable to the Department's requirements and of their objection to purchase the old Avenue plant. The switchboard at the company's Avenue Exchange was of the self-restoring indicator branching multiple type. It was installed in August 1894 and has received mention in Chapter XI. It was very largely served by overhead means and doubtless would have been displaced by a modern exchange in the interests of the company had not the company's term of licence been limited as it was. The plant installed by the Post Office in connection with the Avenue exchange was therefore in duplication of the company's plant in regard to the exchange, and the subscribers' lines and apparatus. The new Avenue Exchange was also interesting for the reason that it was the first exchange in this country equipped for ancillary jack working.

The ancillary system had been in use for some time in New York and was nothing more than the provision of electro-mechanical facilities whereby it was expected that the operators might co-operate in team working to a greater extent than was permitted by the usual single answering jack. In addition to the customary combination of line lamp and answering jack comprising the answering equipment for each subscriber's line, two similar lamps and jacks per subscriber's circuit, termed ancillaries, were provided at other predetermined operators' positions on the switchboard. The primary answering jacks

and lamps were placed in the lowermost position of the panel, as usual, and the ancillary jacks and lamps above them. Each operator attended first to the subscribers represented by the primary answering jacks and lamps definitely allotted to her. On occasions when she had no calls to answer on her own primary answering jacks, she first attended to any calls which might be unanswered on the operators' primary positions on either side of her, and if these were clear, replied to any calls waiting as indicated on her own ancillary equipment.

Avenue was an exchange with high calling rate, approaching 20 calls per subscriber per day, and a high proportion of junction

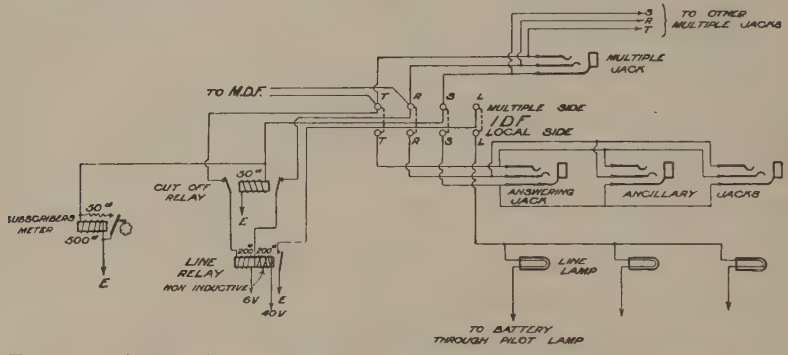

FIG. 135.—Avenue Common Battery Exchange, London, 1912. Subscriber's line circuit with ancillary answering equipment.

traffic, 76 per cent. of the total originating calls being for subscribers on other exchanges. For the latter-mentioned reason there was no subscribers' multiple provided on the "A," or subscribers' sections, all calls being dealt with by "A" operators through order wires.

The "B" boards were equipped for keyless working. Immediately the originating operator completed the connection after the "B" operator had allotted the junction and inserted the plug in the multiple jack of the wanted subscriber's circuit, ringing current was automatically transmitted to the called subscriber's line through the "B" operator's junction cord and plug. There were 30 junctions per position with a permissible ultimate of 36.

The design of the Avenue Exchange equipment was similar to that of the Glasgow and Willesden exchanges, previously mentioned, except for the ancillary equipment and keyless junctions. The line circuit is shown in Fig. 135. It was supplied

and fitted by the Peel Conner Telephone Works, Ltd. The exchange was brought into service on Saturday, January 14th, 1912, and the demolition of the old Avenue Exchange was at once put in hand. A unique feature of the old Avenue Exchange was the peculiar erection on the roof for the support of aërial lines. It consisted of 39 tubular standards arranged in the form of an octagon, and connected by iron arms, for support of overhead wires. From the illustration in Fig. 80 it may be observed that its appearance was not unlike that of the supporting framework of a large gas-holder. The transfer from old to new Avenue involved treatment of 3421 direct exchange lines with 8092 associated telephone stations.

Expert opinion now is that ancillary working was a failure and in no exchange in this country other than Avenue has this feature been introduced. The anticipated advantages were never realised, owing to the fact that operators delayed plugging in to answer a call on the ancillary jacks, in the hope that it would be taken at another position.

The system also introduced complications in the switchboard cabling, and rendered more difficult extensions of the exchange equipment.

By January 1st, 1912, when the dual telephone administrations became one, under State control, the number of subscribers' direct lines connected to Post Office exchanges in the Metropolitan area had grown to 52,964; at the same time the National System served 74,775 lines, making a grand total of 127,739 direct exchange lines in the Metropolitan telephone area. The number of telephone stations corresponding to these figures were, Post Office 77,315, National 131,506, total 208,821.

The Post Office system comprised 33 exchanges, including the official switch, Treasury and trunk exchanges, and the National Telephone exchanges transferred to the Post Office numbered 62, including Bartholomew House Exchange.

Table 13 is a list of the Post Office and National Exchanges as they existed at the time of the transfer, *i.e.*, January 1st, 1912, together with the number of subscribers' direct exchange lines connected to each.

Fig. 134 shows geographically the positions of the various public exchanges of the Post Office and the National Telephone Company as they existed at this time in the Metropolitan telephone area.

Tables 14 and 15 give particulars of the common battery exchanges provided by the Post Office in the Metropolitan area, and the development of the system from 1903 to 1912.

Fig. 136 is a graph representing the growth of direct exchange lines in the Metropolitan area from 1902 to 1912. The progress of the National Telephone and Post Office systems is denoted separately, and the respective percentage increases each year are also given in curve form. The total development in the

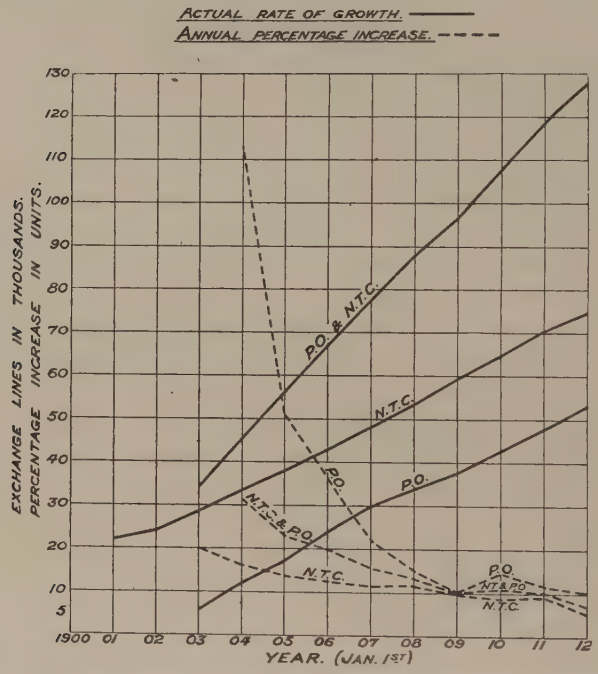

FIG. 136.—Graph showing actual and percentage telephone development in the Metropolitan Area, 1902–1911.

Metropolitan area in telephone stations from 1880 to 1924 is graphically indicated in Fig. 186.

During the ten years preceding the acquisition by the Post Office of the National Telephone Company's plant on January 1st, 1912, apart from the activity which occurred in London, and the opening up of telephone service in many rural districts in the country, the Post Office had occasion to enter the field of telephony in Glasgow earlier than was originally intended; as recorded in Chapter XIV, the Glasgow Corporation tele-

phone system, inaugurated in 1901, was sold to the Post Office in 1906, so that from 1906 to 1912 the Post Office and the National Telephone Company were jointly responsible for the telephone service in the Glasgow telephone area. The number of exchanges comprised in the Corporation system, and which passed into the hands of the Post Office, was 20.

In Chapter XIV a brief account is given of the Glasgow Municipal telephone enterprise, and mention is made that for the largest exchange, viz., Central, as well as for four smaller ones, the Corporation adopted the call wire system and installed switchboards with a flat or horizontal multiple. At the time the Post Office acquired the system these boards were out of date after giving service for a period of but five years, and it was soon decided that, to provide an efficient telephone service for the subscribers connected to the call wire exchanges, it was essential that modern common battery exchanges should be substituted for the obsolete switchboards.

In order that systematic steps might be taken towards the unification of the system, and to avoid duplication and overlapping of plant, a working arrangement was arrived at between the Post Office and the National Telephone Company; consequently from the time of the acquisition by the Post Office of the Glasgow Corporation telephone system to the end of 1911 the operations of the two administrations were so closely interwoven that they cannot readily be dissociated and therefore will be dealt with conjointly.

Out of the working agreement referred to arose the transfer, on Saturday, April 17th, 1909, of some 3200 subscribers from the old Corporation Exchange, Hillhead, to a new common battery 10,000 line exchange of the same name, provided by the company to serve the districts of Hillhead, Kelvinside, Dowanhill, Partick, Partick Hill, Jordanhill, Whiteinch, Scotstoun and Scotstounhill. The new exchange was situated at the west corner of Caledon Street and Highburgh Road, Dowanhill, and was housed in a building of imposing appearance. The equipment installed was of the Western Electric Company's standard common battery type.

On Saturday, August 13th, 1910, the policy adopted by the Post Office, in which the National Telephone Company cooperated, was continued by a further step, when another new

exchange was opened, on this occasion by the Post Office, in the handsome pile of Post Office buildings situate in Waterloo Street. This exchange replaced the ex-Municipal Central Exchange, from which approximately 5000 subscribers' exchange lines were transferred.

To this exchange exceptional interest attaches. At the time of its opening it was the largest common battery exchange, exclusively of British manufacture, to be installed in this country. The equipment was wholly contained on one floor of the building mentioned and was manufactured and fitted for the Post Office by the Peel Conner Telephone Works, Ltd., Salford; it embodied several new features and developments in telephone exchange practice.

The switchboard consisted of 28 three-position subscribers' sections and 12 junction sections. The full capacity of the multiple was 14,400 and it was fitted for 10,000. Each operator's position was equipped with 120 answering jacks and lamps, which could be increased to 150. Outgoing junctions numbering 960 multipled every two positions were provided. Each junction position accommodated 26 incoming junctions.

Important features were, the adoption of a working voltage of 40 in place of the usual 24, the abolition of the repeating coil in the operator's cord circuit and the inclusion of condensers in the speaking circuit. In the latter respect the cord circuit was somewhat similar to that adopted by the British Insulated and Helsby Cables, Ltd., in the Post Office exchange fitted by them at Cardiff in October 1910. Diagrams of the connections of the subscribers' line circuit and operators' cord circuit are given in Fig. 137.

A complete description of this exchange was given in an article by Mr. J. W. Turner in the *Post Office Electrical Engineers' Journal* for January 1910.

The new Central exchange served not only to accommodate all the subscribers previously connected to the Municipal Central Exchange, but also, at a later date, approximately 2000 of the subscribers to the National Telephone Company's Royal Exchange, arrangements being made between the Post Office and the National Telephone Company for their transfer.

From the date of opening the new Central Exchange to the end of 1911, when the National exchanges and plant were added to the

Post Office system, new common battery exchanges were opened at Rutherglen, Shettleston, Bell, Bridgeton and Queen's Park.

Equipment at the new Central Exchange fortunately served to provide for an emergency caused by a disastrous fire at the

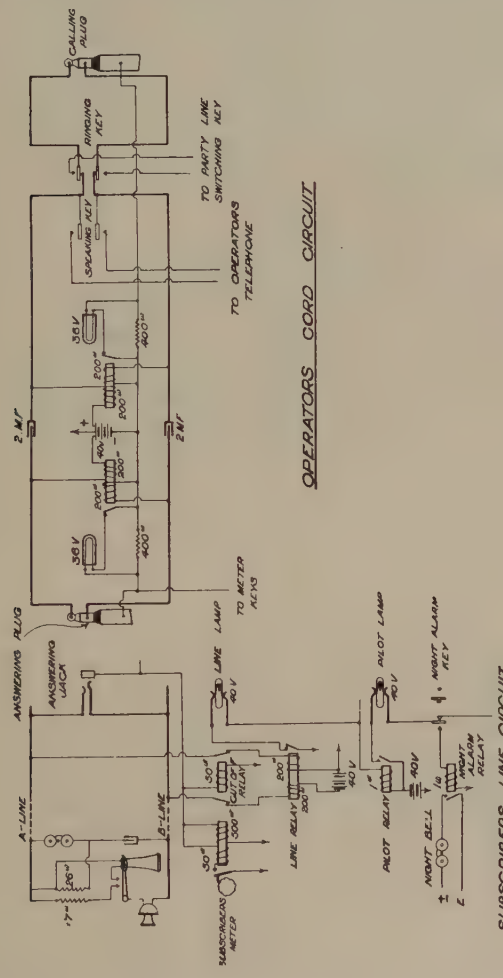

FIG. 137.—Line Circuit and Operator's Cord Circuit, Post Office, Glasgow Central Common Battery Exchange.

ex-Corporation Bell Exchange, prior to the opening of the new Bell, then in course of construction; the subscribers' lines were temporarily diverted to, and worked from, the Central Exchange pending the completion of the Bell.

On August 19th, 1911, another new common battery exchange was opened by the National Telephone Company. It was

situated in Renfrew Street, and was in substitution of the old historic Douglas Exchange, which comprised a flat switchboard fitted with lamps and operated on the ring through system. At the new Douglas Exchange, multiple equipment for 4000 lines, and answering equipment for 3820 lines, were initially fitted; the ultimate capacity was for 7000 lines.

On August 26th, 1911, the Douglas Exchange received a further complement of subscribers' lines, by diversion to it of subscribers from the National Royal and the Post Office Central Exchanges, and at the date mentioned the Douglas Exchange gave service to approximately 3000 subscribers.

The Douglas Exchange is an interesting link between the present time and the earliest days of telephony in Glasgow; the original Douglas Exchange, situated at 140 Douglas Street, was the first telephone exchange to be established in Glasgow. It was originally opened by Messrs. D. and G. Graham, from whom it was acquired in June 1881.

Unification of the Glasgow telephone system proceeded and approached finality on December 16th, 1911, with the diversion of the remaining portion of the subscribers connected to the Royal Exchange of the National Telephone Company, and of the whole of the subscribers served by the Tron and Bridgeton, ex-Municipal exchanges, to new exchanges provided by the Post Office, viz. Bell and Bridgeton. The demolition of the old exchanges thrown out of use was proceeded with immediately.

Cardiff was one of the few places where the Post Office provided an exchange telephone service in competition with the privately owned system practically from the inception of commercial telephony. By about 1907 the National Telephone Company's Central Exchange at Cardiff had outgrown the capacity of the building; the Post Office had abandoned the old exchange worked on the permanent current system, and had already opened a common battery exchange in lieu thereof; in order to provide satisfactorily for development of the telephone system arrangements were made whereby the Post Office was to provide a new exchange for the use of the National Telephone Company, to whom it was to be leased, for the remainder of their tenure of licence. The initial equipment was for 4600 subscribers, and the scheme provided for an ultimate 10,000 line exchange, by suitable extension when required.

The " A " board comprised 12 nine-panel sections, with a three-panel dummy at each end. Each operator's position embraced three panels accommodating 150 answering jacks and lamps, 120 only being fitted at the outset. The complete

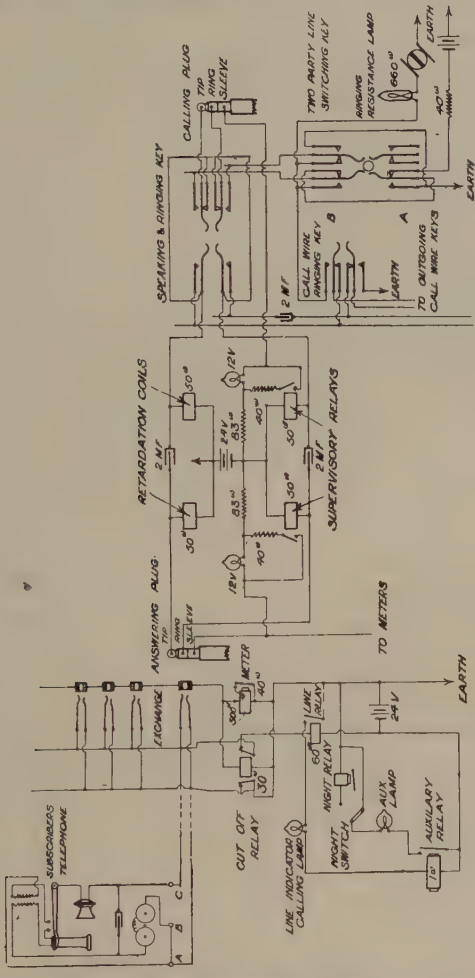

FIG. 138.—Line Circuit and Operator's Cord Circuit, Post Office, Cardiff Common Battery Exchange.

multiple was for 4600, multipled every eight panels. Outgoing junction equipment of 100 multipled every six panels was provided, the ultimate being 600. The " B " positions were two three-position sections, each position accommodating 27 incoming junctions. Subscribers' lines and outgoing junctions on the " B " positions were multipled every six panels.

The equipment was supplied and fitted by the British Insulated and Helsby Cables, Ltd.

The operators' cord circuit on the subscribers' sections was a modification of the Stone system, and differed from the customary systems where repeating coils were used. The subscribers' line circuit and operators' cord circuit connections are set out in Fig. 138. Current was fed to the subscribers' lines from a 24-volt battery through the supervisory relays and retardation coils, which served as the impedances, the chief feature of the Stone system. Condensers, connected as shown in each side of the cord circuit, afforded a path for the high frequency speech currents.

The new exchange was opened in October 1910, when the subscribers formerly served by the New Street, Roath, Canton and Cathays exchanges were transferred.

For the smaller exchanges opened by the Post Office in various country districts in the Provinces, and also in the Metropolitan area, the system of working adopted was known as the Central Battery Signalling System. This system has been used almost exclusively by the Post Office for small exchanges since 1902. It was developed by Post Office engineers with the purpose of securing for small exchanges, where the expense of full common battery working was not justified, and where primary batteries must usually be relied upon for supplying the requisite energy, the advantage of automatic calling and clearing which is a marked feature of common battery working. A further advantage claimed for the system is the permanent test to which the line circuits are subjected by the voltage constantly impressed upon each line under normal conditions.

The system involves the use of a primary battery at each subscriber's instrument for speaking purposes, but otherwise the subscriber's apparatus is not dissimilar from that used in ordinary common battery working. At the exchange, a 24-volt battery is required for signalling purposes; this battery is usually provided in duplicate, one set of cells as a standby.

The line circuit and cord circuit connections for a non-multiple exchange are shown in Fig. 139. It will be seen, by examination of the diagram, that the calling signal is given when the receiver is removed from the switch-hook; the indicator is actuated by the 24-volt battery situated at the exchange, common to all the

subscribers' circuits. On the operator inserting the answering plug into the subscriber's jack, battery is connected to the centre point of the windings of the differentially wound supervisory signals, through the bush of the jack and sleeve of the plug,

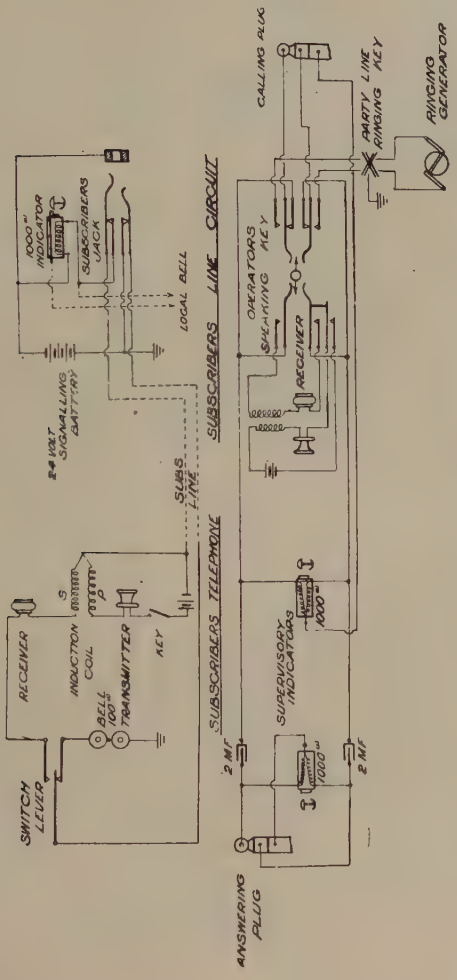

FIG. 139.—Line Circuit and Operator's Cord Circuit, Post Office Common Battery Signalling System for small exchanges.

conversation being maintained by local batteries. The subscriber is called, by an earthed generator, through the " a " line and subscriber's 100-ohm magneto bell. On the subscriber replacing the receiver after conversation, the clearing signal is received at the exchange by current circulating from the common

signalling battery through one coil of the supervisory indicator, "a" line and subscriber's 1000. bell.

The common battery signalling system directly replaced the permanent current system previously regarded as the Post Office universal system, and referred to in Chapter V.

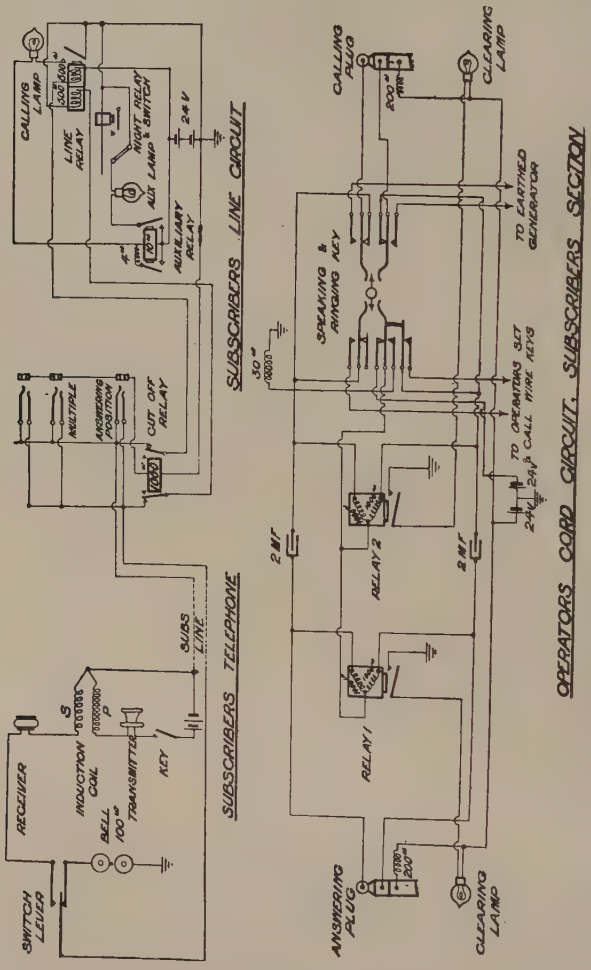

FIG. 140.—Post Office Common Battery Signalling System. Multiple Switchboard, Newcastle-on-Tyne, June 1906. Circuit Connections.

The common battery signalling system has been adapted for multiple working also, and numerous common battery signalling multiple exchanges have been established by the Post Office. The smaller suburban exchanges originally opened in London, immediately following the entry of the Post Office into the tele-

phone field, where ultimate accommodation for not more than 1000 lines was anticipated to suffice, were originally equipped with common battery signalling switchboards; the N.E. (N) or Heaviside system established at Newcastle-on-Tyne and

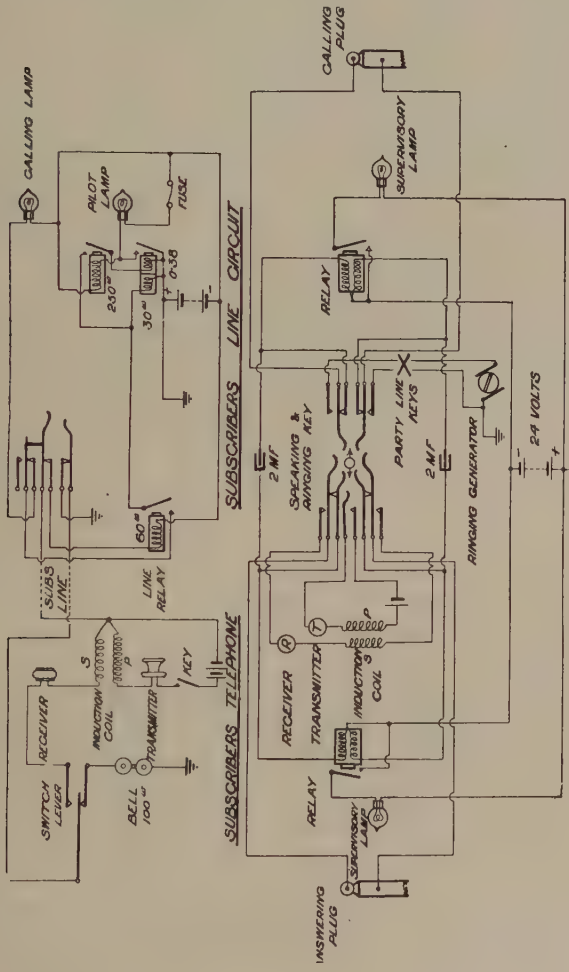

Fig. 141.—Line Circuit and Operator's Cord Circuit, Post Office Common Battery Signalling System with lamp signals.

neighbourhood in 1882, described in Chapter XI, was replaced by a common battery signalling multiple switchboard in June 1906, the subscribers' line circuit and operator's cord circuit connection being given in Fig. 140.

The line and operator's cord circuit connections of the early common battery lamp signalling exchanges are given in Fig. 141.

CHAPTER XVI

OVERHEAD LINE PLANT, 1843–1922

When the telephone was first introduced into this country, the British Post Office was in every way most favourably situated to institute telephone service. Not only was the Post Office the only administration possessing and working telegraph lines for the public convenience (having acquired them from the private telegraph companies in 1870), but it was served by a staff of engineers well trained and experienced in the construction and maintenance of telegraphic plant of all descriptions. It was also in possession of certain legal powers in respect to the installation of telegraphic lines in public and other thoroughfares, which placed it in an unique position in this respect. The Government, however, decided to permit private enterprise to exploit the telephone, and the Post Office was thus deprived of the advantages which might have been secured had the telephone been acquired and worked by that administration from its inception. Whereas the Post Office possessed the material advantages mentioned, the several telephone administrations formed soon after the invention of the telephone had none of them and they were perforce compelled to proceed as best they were able. At the time of the commercial introduction of the telephone, telegraph engineering practice had settled down on more or less standard lines, and bare overhead wires of galvanised iron, secured to insulators of earthenware or porcelain, supported by poles fixed in the ground, or on buildings, were generally employed.

In order to follow from its commencement the development of overhead line construction, it is therefore necessary to revert to the early days of the telegraph. It is not intended to treat fully of the various phases of development of overhead line plant for telegraph purposes prior to the introduction of the telephone, but some particulars relative to what appears to be the real

starting point of a practical open wire line system will perhaps not be without interest.

In Chapter VIII reference is made to a system of underground work devised by Mr. W. F. Cooke as early as 1843, wherein the insulation of cotton-covered conductors, contained in iron tubing, was maintained by means of dry air. The pages of the *Practical Mechanic* for July 1843, and also of the *Engineering Magazine* of the same year, contain a description of Mr. Cooke's underground system, and also of a method of suspension and insulation of overhead conductors at that time superseding the underground plant previously in use.

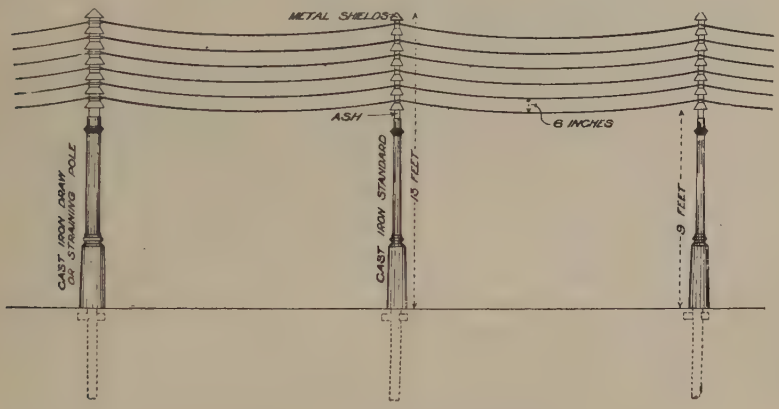

FIG. 142.—Cooke's open wire line system, 1843.

For many years past telephone engineers have been, and they still are, engaged in adding considerably to existing underground systems, and in the installation of underground cables in places previously served exclusively by overhead means, and in the consequential displacement and recovery of a large amount of overhead plant. Such has been the general practice for many years owing to the rapid development of the telephone service. It may, therefore, be difficult for present day engineers to appreciate that in the early history of telegraph line practice the reverse process was actually going on in various parts of the country, and that overhead wires were erected in substitution for underground cables which had not proved satisfactory. In the *National Telephone Journal* for April 1909 (Volume IV, page 16) an article appears culled from the pages of the *Practical*

Mechanic, previously alluded to, in which particulars are given of one of the first overhead lines to be erected. The system was devised by Mr. Cooke for telegraph purposes, and is of unusual interest, as it appears to mark the commencement of the systematic use of overhead wires for telegraph purposes, and to constitute the origin of our present day overhead line systems. That portion of the article referring to the use of overhead wires is therefore reproduced below, and a drawing, from particulars quoted in the article, illustrating Mr. Cooke's arrangement of overhead wires is given in Fig. 142.

"The plan consists in firmly fixing into the ground, at every 500 or 600 yards, strong posts of timber, from 12 to 18 feet in height. On the tops of these posts is a series of winding apparatus, corresponding to the number of conducting wires to be employed; and between every two such posts, upright wooden standards are fixed, from 60 to 70 yards apart. A ring of iron wire (No. 7 or 8) which has been formed by welding the short lengths in which it is made together, is then placed upon a reel carried on a hand-barrow, and one end being attached to the winder at one draw-post, the wire is extended to the adjoining draw-post, and there fixed to its corresponding winder; by turning the pin of the ratchet-wheel with a proper key, the wire is tightened to the necessary degree; thus the greatest accuracy may be attained in drawing the wires up till they hang perfectly parallel with each other. To sufficiently insulate the wires so suspended at the point of contact with the posts is an object of indispensable importance, as the dampness of the wood during rainy weather would otherwise allow the electric fluid to pass off freely into the earth or into an adjoining wire, and thus complete the circuit without reaching the distant terminus at which the telegraphic effect is to be produced. In this, indeed, lies an important feature of Mr. Cooke's invention, as the mere idea of supporting wires in the open air from poles, trees, or church steeples, is the oldest on record. To effect this object, at the draw-posts wooden boxes to enclose that portion of the post to which the winders are attached, and small openings are left for the free passage of the wires, without risking any contact with the outer box. The standards are furnished either with covers parted off by an overhanging roof between each wire, and again between the lowest wire and the earth, or by a series of metal shields. An eye of metal, with a slit on the upper side, forms a hook to support the wire, which has a split quill slipped over it at the point of support, to insulate the wire from the hook, which might otherwise act as a conductor to the dampness in the wood. The whole is then carefully painted with several coats of anti-cor-

rosion paint—or asphalte varnish may be employed for the wires. When the wires are to be varnished, they are unhooked from the upper ends of the standards, and lowered to nails temporarily fixed to receive them toward the bottom of the posts. A painter, furnished with a can of paint hung on his shoulder, a brush, and a piece of felt, takes each wire and rapidly coats it, when it is again hooked up in its position at the top of the standard. This is the simplest and cheapest method now adopted. But for long distances Mr. Cooke employs earthenware or glass for his insulation, and cast iron standards and posts, with ash tops, for drawing and suspending the conductors, which instead of single wires, will be strands of six or more wires twisted together. For very great distances, when very superior conducting power will be needed, a copper wire will be placed in the centre of the strand, and whilst it adds but little to the weight, it will more than double the conducting power thereof, the iron wire still giving the necessary strength to resist tension. The relative conductive powers of copper and the softest iron wire are nearly as seven to one. Various methods are adopted in passing under bridges, which answer the purpose of draw-posts, the winders being fixed to a piece of wood partly let into the brickwork, to avoid damp (the greatest enemy to electric conduction); earthenware insulators are also introduced between the winder and wire. Mr. Cooke also intends to use caps or boxes of earthenware to surmount the iron standards.

"At Slough, for half a mile in approaching and passing by the station, cast iron standards and draw-posts are employed, the effect of which is remarkably light and elegant. A line of six wires is there completed: and in crossing over a carriage shed immediately opposite to the station, the wires are stretched over a length of 438 feet without any intermediate support; and so accurately are they arranged, that no difference is perceivable in their parallelism. The draw-posts in this instance are half a mile apart, although the line is slightly curved. In passing over a station or an accommodation-road, or in crossing the railway, loftier standards are employed, which abruptly lift the wires to the height of 25 or 30 feet, in order to clear objects passing below. In the latter case lighter wires are employed, that the tension out of the direct line of strain may not draw the standard from the perpendicular.

"The ordinary precaution of charring, pitching, and kyanizing the posts is carefully attended to; but in case of the decay of a standard near the earth, then it is only necessary to provide a new piece for the bottom, to which the upper portion can be spliced. The method of letting the standards into the earth is novel and convenient. For this purpose Mr. Cooke employs a boring tool accurately agreeing in size with the iron standards,

and rather larger for the wooden ones. The level, taken from the rails, gives the depth to which the standards are to be sunk, which is chalked on the boring tool, and in the course of a few minutes, where the soil is suitable, the hole is opened and the standard fixed and rammed closely round the sides without the soil being disturbed.

"An admirable point in this system is its adaptation to cases where a telegraph is only occasionally required, as in the repairs of railways, when one line is temporarily closed on the falling of a bridge or slipping of an embankment, as occurred on the Croydon line. The materials being kept ready in store, are conveyed to the spot, the holes bored for the posts, the wire strand run in, and the telegraph is working in a few hours. Upon the necessity ceasing, the strands are again wound up, the posts lifted and sent again into store, in readiness for the next emergency.

"One obvious advantage which this plan has over the old one of laying the wires in tubing is the facility of repair which it allows; and in point of first cost it has likewise a decided advantage. The cost of the original plan with tubing stands nearly as follows:—

Prepared ¾ tube, varnished within and without, 5¼*d.* per foot	£115	10	0
Six copper wires, covered and varnished, at £6 15*s.* per mile	40	10	0
Labour and carriage, per mile	27	0	0
Iron fittings, boxes, etc.	12	6	0
Tar, pitch, paint, resin and sundries	15	0	0
Post and rails, at 3½*d.* per foot, including fixing	77	0	0
Making the total cost per mile	£287	6	0

To this a percentage for casualties, profit to the contractor, and the price of instruments, remain to be added.

The present plan of suspension may be estimated thus:—

Six iron wire strands or ropes	£48	0	0
Drawing posts, with winding apparatus, and cast iron standards with insulators	52	0	0
Labour in fixing and painting, per mile	12	6	0
Anti-corrosion paint and tar, per mile	11	0	0
Carriage, tools and sundries, per mile	13	0	0
Contingencies, per mile	13	0	0
Total, per mile	£149	6	0

making a reduction of about 50 per cent. in favour of the present plan, and a still greater advantage in favour of the permanency of the work."

Much investigation and many experiments and trials followed Mr. Cooke's invention before a system of overhead wires which satisfactorily fulfilled the conditions for telegraph working on a practical commercial scale was evolved.

The line requirements for the new service of telephony were, however, in some respects dissimilar from those of the telegraph; telegraphic communication was for the most part between one town and another and therefore the telegraph lines extended between town and town. The telephone, on the other hand, was at first chiefly required to serve for purposes of communication between one point and another in the same town, and no routes on which the requisite wires could be erected were in existence. The telephone companies were therefore compelled to erect entirely new plant.

In the early stages of telephone service the engineers of the different administrations each held their own views regarding methods of open line construction and individually followed them. Consequently, in minor matters early line practice differed considerably in various parts of the country. Some of the early construction was, in the circumstances, somewhat crude and would be regarded by present day engineers as far from satisfactory. Nevertheless, it served its purpose in giving a service for which, in those days, certain allowances were made, and in establishing the practicability of the telephone as a means of communication. In the early days numerous classes and denominations of line wire were employed. Bare galvanised iron wire of No. 12 B.W.G. was, perhaps, most commonly used, but 60 lbs. galvanised iron wire, a stranded galvanised conductor made up of three strands of No. 16 B.W.G. wire, and even No. 16 B.W.G. copper wire, in fact, almost every conceivable class of wire at all suitable, and some perhaps which was not, was employed. Some engineers considered that in towns, bare iron wire, although galvanised, would not resist satisfactorily the corrosive influences of the atmosphere, and the wire used was therefore enveloped in a covering of cotton or other similar material, impregnated with acid-resisting and weather-proof compounds, thus adding to the weight to be supported and to the unsightliness of the conductors. For leading-in wires at exchanges gutta-percha insulated copper wire was invariably used.

Line plant was at first largely erected upon the house tops

and in London almost wholly so. In the course of the first few years in the history of the telephone in this country the means of support for overhouse wires erected on the roofs and walls of buildings were of a novel and even fantastic form, but as the service expanded more serious attention was devoted to the design of overhead line plant, particularly roof structures for the support of wires, and gradually more or less uniform designs were evolved.

The general use of overhead lines supported upon roofs led to the practice commonly adopted of establishing exchanges on the uppermost floors of conveniently situated buildings, which offered on their roofs suitable facilities for supporting the radiating wires, a practice largely followed to this day, but for another reason, namely, the improved natural lighting secured.

At first, wires were run as required, without any very considered attention being accorded to the question of future requirements, but as the system grew, as the lines gradually extended further and further from the exchange, and as the number of wires to be carried increased, some more comprehensive system of overhead distribution became necessary.

As stated, for a few years after the introduction of the telephone, telegraph practice was followed in the use of galvanised iron wire for overhead lines, and, up to 1880–1882, wire of that material was almost exclusively used throughout the country. At this period the growth of systems of overhead wire was such that engineers became much concerned as to how future requirements were to be satisfactorily provided for, and the need for a more suitable material than iron for telephone (as well as telegraph) wires was realised. Consequently, both in this country, and also abroad, considerable attention was directed towards the production of a wire superior to iron, and the final result of a few years' research and experiment was the introduction of copper and bronze wires such as are now universally used, in the circumstances briefly to be related.

The chief considerations which weigh in the choice of a material for wire for overhead purposes are :—

(*a*) Tensile Strength.
(*b*) Conductivity.
(*c*) Durability.

(*d*) Initial cost.
(*e*) Bulk.
(*f*) Weight.

Wire of galvanised iron possessed the important advantages that its tensile strength was high, and that it was cheap; it suffered, however, the objections that it quickly deteriorated when subjected to the vagaries of the British climate, particularly in towns and cities where the atmospheric conditions were most unfavourable, owing to the presence of acid impurities, and, incidentally, where also the number of wires to be provided and maintained was greatest. Its conductivity also left much to be desired, iron being both bulky and weighty for a given conductivity. Its electromagnetic inertia was another factor to be contended with.

Generally considered, materials which possessed the requisite tensile strength were, unfortunately, relatively poor in electrical conductivity. The cost of the best conductors was proportionately high and their durability superior. Tensile strength and conductivity could obviously be improved by suitably increasing the diameter, but the disadvantages of the additional weight to be supported, the increased bulk exposed to wind pressure and the enhanced cost were serious. The question was therefore somewhat involved and appeared largely to be one for compromise.

At the International Exhibition of Electricity, held in Paris in the year 1881, bare wires for aërial lines were shown in great variety, especially in the French departments. Wires of galvanised iron, copper, brass, malleable bronze, cast steel together with bimetallic wires were exhibited. The prospect opened up by the development in telephony gave an impetus to manufacturers to produce a wire which was an improvement on galvanised iron.

At this time the use of phosphor bronze in the manufacture of wire received a good deal of attention, and phosphor bronze was put forward in numerous quarters as an ideal material for telephone line wire. The requirements imposed by telephony were considered to be somewhat exacting. The extensive use of overhouse wires rendered the question of weight an important factor, and conductivity was considered subordinate to mechanical requirements.

Prior to the general introduction of hard drawn copper wire,

there were numerous instances where copper wire produced with only the normal amount of drawing and left unannealed had been used. The employment of copper wire was provided for as early as 1843, in the system devised by Mr. Cooke, previously alluded to, and its superior conducting properties were even then well recognised. Mr. Thomas Bolton, of Messrs. Thomas Bolton and Sons, Ltd., a firm of wire manufacturers established as far back as 1783, to whom the author is indebted for some interesting information relative to the early manufacture and employment of hard drawn copper wire for telegraph and telephone purposes, remembers at least one case where overhead copper wire was used not later than 1865.

Although the superiority of copper, in so far as conductivity was concerned, was well known, its low breaking strain and limited elasticity were sufficient to preclude its use generally. Another disadvantage considered highly prejudicial to the use of copper was that its high intrinsic value would be conducive to theft; this idea may to-day seem somewhat extreme, but nevertheless it was one with sound foundation, as after events proved. There have been numerous occasions when overhead copper and bronze telegraph and telephone lines have been raided and quantities of wire carried off, especially during periods in which there was a boom in the price of the metal.

It was early in the decade 1880–1890 that the Post Office seriously took up the question, and consideration was given to the introduction of copper, in view of its superior conductivity and durability, and the advantage to be gained in the decreased weight to be supported for the same conductivity as compared with iron wire. The hardening effect of drawing was well known from the first, and was taken advantage of where " spring " or rigidity was required, but for most purposes it had been the practice to anneal drawn wire before use. The idea of employing copper drawn really hard, in order to impart to it the requisite tensile strength which otherwise it lacked, originated with the Post Office, and under the direction of Sir William (then Mr.) Preece, some experimental lines were erected, but they failed because the wire was too brittle. Durability under adverse atmospheric conditions was tested by exposure of samples of wire in Primrose Hill Tunnel, and the result was greatly in favour of copper.

At the period under review, electrolytic copper was little used; most wire for electrical purposes was manufactured from fire-refined Chili copper and was annealed before use, little attention having been given to its mechanical properties.

Messrs. Thomas Bolton and Sons, who, however, had their own electrolytic plant, were then approached by Mr. Preece, and they laid themselves out to produce a suitable wire of copper. The collaboration between Mr. Preece and Messrs. Bolton resulted in the preparation, from electrolytic copper, at the firm's works at Oakamoor, of a number of samples of wire drawn to varying degrees of hardness; these were carefully tested both for tensile strength and pliability. The result of the experiments was satisfactory, and finally a specification was drawn up for wire of 100, 150 and 200 lb. weight per mile; this specification has remained practically unaltered ever since.

In the very early days wire was beaten out by hand, but in the fourteenth century drawing out through dies was introduced for the later stages, the work still being performed by hand. Eventually, power was applied to the drawing process. Mr. Thomas Bolton says that he has seen a plate from a power-driven wire mill of the eighteenth century, the metal being rolled into strips and slit preparatory to the operation of drawing.

In 1880 the method of manufacture still was to roll the copper into long strips, which were slit into a number of narrow shreds, to be subsequently drawn into wire. Such a method was, however, found to be unsuitable for the heavier gauges of wire in contemplation for long lines, owing partly to limitation in length of coils and partly to the sheared edges being detrimental to the production of satisfactory wire when the copper was thick.

Messrs. Thomas Bolton and Sons were, however, at that time busy with the installation of a rod rolling mill which removed this difficulty, as well as others, but great care was still essential, both in heat treatment and mechanical methods, to secure the requisite standard of quality. The method of rod rolling, preparatory to drawing, originally introduced by Messrs. Bolton has since been universally adopted.

The production of hard drawn copper wire of any reasonable thickness thus became an accomplished fact and Messrs. Thomas Bolton and Sons manufactured all the copper wire required by the

Post Office, until, eventually, manufacturers of iron and steel wire undertook the drawing of copper.

Some short lines of the new wire were first erected; one was in the neighbourhood of Swansea; the earliest long line was one between London and Newcastle, and consisted of 100 lb. hard drawn copper wire, manufactured by Messrs. Thomas Bolton and Sons. In 1885, before Section A of the British Association, Mr. Preece gave some particulars of the behaviour of this copper line. The experiment was quite successful, and led to the erection of four wires of copper of 150 lb. per mile, for circuits between London and Dublin, in connection with a new submarine cable laid between Nevin, in North Wales, and Newcastle, near Wicklow. The breaking weight of the wire used for this line was specified to be 490 lb., equivalent to 29·5 tons per square inch, but with the actual wire manufactured much better results were obtained; the stipulated figure was considerably exceeded and averaged 513 lb., or 30·6 tons per square inch.

It was soon found that copper wire needed much more care in manipulation than the galvanised iron previously used, and consequently the methods practised in the erection of wire were revised. New rules were therefore drawn up. It was customary to regulate the sag of iron wires by reference to a dip of 24 inches in 100 yards, variations for spans of different length and at different temperatures being provided for in tables supplied to the construction foremen. Special dynamometers were designed and employed to ensure that wire was always regulated to the proper tension. A factor of safety of 4 was employed in preparing the new tables.

Avoidance of surface abrasion was of particular importance, in order that there should be no diminution of the initial tensile strength imparted to the wire in the drawing process.

For securing the line wire to the insulator, soft copper binding wire weighing 50 lb. per mile was adopted.

Owing to the higher coefficient of expansion of copper, the regulation of copper and iron wires erected on the same poles created a difficulty and some departure from the standard figures for both copper and iron was therefore permitted in order to maintain satisfactory mutual regulation.

The introduction of hard drawn copper by the British Post Office was soon followed by its adoption for similar purposes

by the leading railway companies. At the time hard drawn wire was being developed, the telephone trunk line system was in its early infancy, but as it progressed, the advantage of copper for long distance communication was soon recognised, and it was adopted generally by the telephone companies; bronze wire was retained for local lines owing to its higher tensile strength.

The successful manufacture of bronze wire and its application to the requirements of telephone lines was a development earlier and quite separate from that of hard drawn copper wire. M. Lazare Weiller, of Angoulême, France, a French manufacturer, appears to have been primarily instrumental in promoting the employment of phosphor bronze wire. It appears to have been extensively used first in Austria. Phosphor bronze is in some sense improperly so-called, inasmuch as the alloy contains little or no phosphorus. It was produced by the deoxidising action of the element phosphorus, which reduced the oxides of copper and tin, the two metals forming its principal constituents. The phosphorus was introduced in the form of phosphate of copper or tin, at the moment of fusion, and it disappeared when the change in the nature of the metal was effected.

The addition of phosphorus was, however, found to be conducive to high electrical resistance, and consequently M. Weiller devoted attention to the production of an alloy, for manufacture into wire, which, while retaining the high tensile strength of phosphor bronze, possessed a higher conductivity. The result was the preparation in 1881 of an alloy now commonly used throughout this country for light telephone wires, and known as silicon or silicium bronze. The silicon copper compound from which the silicon bronze was produced was made by melting, in a graphite crucible, a certain amount of copper, with an admixture of fluorsilicate of potassium, produced glass, chloride of soda, carbonate of soda and chloride of calcium. It was claimed that the action of the silicon on the copper was similar to that of phosphorus. It acted as deoxidiser, and the silica formed, being an acid, was a valuable flux for any metallic oxides remaining unreduced. A formula recommended for silicon bronze specified copper 97·12 per cent., tin 1·14 per cent., zinc 1·10 per cent. and silicon 0·05 per cent. Wire made from this alloy was said to have the same resistance to rupture as phosphor bronze wire, but possessed a much higher degree of electrical conductivity. It was

claimed that silicon bronze prepared by this process retained 70 per cent. as against 30 per cent. for phosphor bronze of the conductivity of commercially pure copper.

Silicium bronze wire was first brought into practical use in this country in about 1884, but owing to its excessive brittleness it was not a success and its employment was for a time abandoned. Improvements in the various manufacturing processes however, ultimately removed this defect. By 1888 its use for subscribers' circuits had become fairly common, and in another year or two had extended generally to the whole of the country. Since that time silicium bronze wire, weighing 40 lb. per mile, has been the standard line wire universally used.

In 1884 the Imperial Standard Wire Gauge was adopted, and swept away the complications and difficulties which arose out of the indiscriminate use of the large number of different wire gauges which had been devised.

Table 16 gives particulars of the mechanical and electrical constants of the several types of line wire employed for telephone purposes by the British Post Office.

The fairway occupied by the various routes of open wires in the centre of large towns and cities, particularly in London, increased so enormously that the introduction of some method of concentration seemed imperative. Both subaqueous and subterranean telegraph lines had been laid in various places, but the time for underground telephone cables, although the idea was by no means new, as may be seen from a perusal of Chapter VIII, had not yet quite arrived. Recourse was therefore had to aërial cable.

The circumstances in which aërial cable had to be used necessitated that its weight should be a minimum, its tensile strength sufficiently high to withstand strain placed upon it by wind pressure and accumulations of snow, and that it should be composed of a material sufficiently durable to withstand climatic influences and especially variations of temperature

It is mentioned in Chapter III that, in London, early aërial cables were composed of a number of gutta percha-insulated wires bound together by hand with prepared tape, and that twenty wire cable of 18/9 gutta percha-insulated conductors, including a core of 3/16 galvanised iron stranded wire, was eventually made in a similar manner. The demand for aërial cable increasing,

arrangements were made for the manufacture of gutta percha cable under factory conditions, the work being undertaken by the Silvertown and Henley companies.

The salient features of the early type of aërial cable with gutta percha insulation, extracted from a specification drawn up for its manufacture prior to 1884 were as follows :—

The copper conductors were of No. 18 S.W.G., of resistance not exceeding 24·4 ohms per mile, insulated with a double coating of best gutta percha to a diameter of 143–145 mils, weighing 32·5 lbs. per mile, and served with a stout twill ozokerit-prepared tape.

The first core consisted of three strands of No. 18 gauge bronze wire served with tarred yarn. These wires were not provided for purposes of suspension, but as an anti-induction device.

The inner layer of seven conductors was laid up round the centre with a right hand lay of one complete turn in 12 inches. The outer layer was formed of thirteen conductors laid up evenly round the inner layer, with a left-hand lay of one complete turn in 16 inches.

An inner covering was of best ozokerit-prepared twill selvage edged tape, $1\frac{1}{4}$ inches wide, laid on with a lap of $\frac{1}{4}$ inch.

The outer covering was braided.

The inductive capacity was not to exceed 0·327 microfarad per statute mile.

In about 1884, when india-rubber began to replace gutta percha as insulating material for electrical purposes generally, gutta percha insulation for telephone aërial cables was abandoned and was substituted by india-rubber. Particulars of the first type of aërial cable in which india-rubber was employed for insulating purposes, manufactured to the United Telephone Company's specification, are briefly as below :—

The copper conductors, of which there were thirty, were of No. 20 S.W.G., with an electrical resistance not exceeding 47 ohms per mile. The dielectric consisted of a covering of pure india-rubber, 120 mils diameter. The insulation resistance was not to be less than 600 megohms per mile, and the inductive capacity was not to exceed 0·334 microfarad per mile. The insulated wire was to be enveloped, before curing, with best ozokerit-prepared felt.

The core consisted of five No. 20 S.W.G. silicious bronze

wires, stranded with a right hand lay, served with tarred yarn to a diameter sufficient to form a solid foundation for the inner layer of conductors.

Twelve conductors as described, laid up evenly round the core, with a right hand lay of one complete turn in 12 inches, bound with a spiral of tape, formed the inner layer.

The outer layer consisted of eighteen similar conductors, laid up round the inner layer, with a left hand lay of one complete turn in 16 inches.

An inner covering was then applied, consisting of best ozokerit-prepared selvage edged twill tape, $1\frac{1}{4}$ inches wide, laid on with a lap of not less than $\frac{1}{4}$ inch, and the whole was finally enveloped in a braided covering.

The firm of W. T. Glover and Co., Ltd., of Trafford Park, Manchester, established in 1868, has for many years been intimately associated with the manufacture of insulated wires and cables of various descriptions for electrical purposes. At an early date in telephone history Messrs. Glover specialised in and secured a reputation for the manufacture of telephone aërial cables of various types. The events which led to the firm undertaking the manufacture of insulated wires for electrical purposes are not without interest, and, therefore, will be briefly related.

At the time the story of the telephone opened, Mr. W. T. Glover was a manufacturer of braids, tapes, boot and shoe laces, stay laces and the like. In 1879 or 1880, Mr. A. T. Turney, who, later on, became closely identified with the manufacture of telephone dry core cable for the Western Electric Company, at North Woolwich, was assisting Col. Gouraud, who, as mentioned in Chapter II, acted for Edison in this country, and formed the Edison Telephone Company of London, Ltd. for the purpose of exploiting Edison's telephone inventions. Mr. Turney, who toured the country and practically demonstrated the utility of the Edison telephone instrument, says that he desired to have some iron wire, which he was about to erect in certain parts of the South of Lancashire, covered as a protection against the corrosive influence of the atmosphere—peculiar to that locality; Mr. Glover undertook to do what was desired by means of certain braiding machines in his factory. This circumstance was one which claimed Mr. Glover's interest, and directed his attention

to the prospect then opening up for he manufactture of insulated wires for telephone purposes.

Mr. Henry Edmunds, at one time partner with the late Mr. Walter Twiss Glover, and destined to become chairman of Messrs. W. T. Glover and Co., Ltd., when formed as a limited liability company, has kindly supplied the author with some further information of interest relative to the early production, by Mr. Glover, of insulated wires and cables for general electrical, as well as for telephone purposes.

As mentioned in Chapter VIII, the plaiting or braiding of wires for electrical purposes by means of a braiding machine was provided for in the patent specification No. 10799, of 1845, by Messrs. Young and McNair of Paisley. It is, however, an interesting and curious circumstance that the practical application of the process of braiding, to the preparation of insulated conductors for telephone and other electrical purposes, developed from a process invented in connection with the manufacture of ladies' crinolines, so fashionable, and much worn, in the period 1856–1866. At the latter date the immense bell-shaped crinolines, sources of so much inconvenience and no little danger to the wearer and her associates, fortunately fell into disuse. Crinoline wire was for many years a leading branch in the steel industry.

Mr. W. T. Glover's father was engaged in the manufacture of braided steel strips, also at one time in great demand for ladies' crinolines. The elder Mr. Glover was associated with an ingenious mechanic, by name James, a Nottingham man, who designed and built for him a number of machines for covering the crinoline hoops with a kind of weaving or braiding. When crinolines went out of fashion these machines were thrown idle and, upon the death of Mr. Glover, senior, they came into possession of his son, Mr. W. T. Glover. Mr. James suggested to him that, by slight modification, the machines might be adapted for braiding electrical wires. The modification was made with successful results, and the braided insulation found to be suitable.

Mr. Henry Edmunds was, at this time, in partnership with Sir Joseph Swan in his foreign patents connected with the Swan incandescent lamp. He was acquainted with Mr. Glover, and informed him of the possibilities opening up for the use of

insulated wire and that quantities would be required. Mr. Glover volunteered to supply a special wire which he thought would be peculiarly suited for electrical purposes. Previously the insulation of wires of the class in question had been formed of cotton wound or lapped round them. Mr. Glover proposed to apply the cotton in the form of braiding, by means of the converted machines referred to, and the manufacture of wire insulated with a braiding of cotton thereupon commenced.

In 1881, the first electrical exhibition was held in Paris and was attended by people from all over the world. At this exhibition, telephone and other electrical apparatus of all descriptions were shown, and braided wire manufactured by Mr. Glover was employed in certain of the electrical fittings exhibited.

Mr. Edmunds' association with Mr. Glover resulted in 1885 in partnership; Mr. Glover specialised in the work of manufacture at Salford, Mr. Edmunds superintending the matter of sales in London. The first London offices were in Hatton Garden and were rented from Mr. James Hicks, the well-known thermometer maker.

The several telephone companies operating throughout the country were apparently eager to avail themselves of the suggestion to adopt Messrs. Glover's braided wires, and an important branch of business was originated.

Amongst Mr. Edmunds' intimate acquaintances was the late Sir William Preece. Mr. George Preece, brother of Sir William, eventually became technical adviser to Messrs. Glover. He had charge of the experimental and testing rooms at the then small works at Salford, Manchester. Mr. George Preece played a considerable part in the design and construction of the various types of cable for which Messrs. Glover became noted.

Incidentally it may be of interest to mention that the Cable Makers' Association, which, as is universally recognised, through its technical department, has done such excellent work in connection with telephone and other electrical cables, originated at a dinner held in 1900 at Dartmouth House, Queen Anne's Gate, Westminster, where the various competitors of Messrs. Glover met by invitation of Mr. Edmunds.

Messrs. W. T. Glover and Company manufactured two forms of cable at one time largely used for aërial purposes. The first was termed "anti-induction" cable. The wires of tinned

copper were insulated with several thicknesses of pure rubber and protected with prepared tape afterwards treated with preservative and insulating compounds. Certain of the insulated wires were coated with tin foil, and the arrangement was such that the foil was in contact with a wide strip of lead foil which enveloped the whole; the lead foil was earth connected and was intended to reduce overhearing. The external protection of the cable was a braiding suitably served and treated with preservative compound. The second type of cable referred to was known as "Magpie," a term arising, no doubt, from the fact that each of the two pairs forming a "quad," of which the cable was composed, were respectively white and black. No tin foil wrapping was applied to individual wires, but an outer wrapping of tin foil was included prior to the final braiding and serving, which, along with the insulation of the individual wires, was similar to that of the former mentioned cable. Cables of this type of 26 and 52 pairs were commonly used. A later type of cable manufactured by the same firm, also of 26 and 52 pairs, was one in which the individual layers were separated and the whole was enveloped by a lapping of tin foil in order to annul cross-talk.

The huge overhead line system gradually built up on the roofs of London is mentioned in other chapters. Its growth was greatly accelerated in 1893, when the task of converting the existing earth circuit lines into metallic circuits was taken in hand. For this work, commenced in 1890 and completed early in 1895, vulcanised india-rubber-covered cables manufactured by Messrs. Glover were extensively used. Particulars of the rubber-covered dry core cable so extensively used in London at one time have already been given in Chapter X.

Although, in America, extensive use has been, and still is, made of lead-covered cables for aërial construction, lead-covered aërial cable has not found much favour in this country. For a long time the possibility of injury or rupture to the sheath of dry core lead-covered cables, suspended aërially, and of damage occasioned by vibration, was sufficient to preclude the use of such cables for overhead purposes, except in isolated instances. There also existed a certain amount of prejudice against the extensive use of large aërial cables, and there was an impression that their existence would be detrimental to the amenities of

certain localities. In America, however, the application of lead-covered dry core cable for overhead requirements was developed rapidly, and methods of construction were devised which, it was contended, largely overcame the objections referred to.

Following upon American practice, the National Telephone Company, in about 1904, commenced the use, in certain suitable cases, of dry core lead-covered aërial cables, and considerable experience in their manipulation was gained in a few years. To some extent the company was influenced in embarking upon the use of such cables by its inability to arrange suitable terms for the installation of underground plant in various large towns and cities, one of which was Glasgow. In London the use of lead-covered cable was severely restricted by the by-laws issued by the London County Council under the Overhead Wires Act of 1891, but in some other places where such regulations were not in force it was used with varying results.

For ground pole work in country districts, the use of lead-covered dry core cable was found to be comparatively simple, so long as certain fundamental but nevertheless important rules were complied with, but for overhouse work the case was somewhat different. It has been argued, however, that lead-covered aërial cable is as adaptable to overhouse requirements as are routes of open wire, and there is perhaps some justification for this contention. The difficulties presented by overhouse work were more in the nature of securing wayleave facilities than of a purely constructional character, and the same holds good for other classes of overhead wire.

Objections urged against the use of lead-covered cable for overhead purposes are as follows :—

(1) Corrosion of the lead sheath due to adverse atmospheric conditions conducive to chemical action.
(2) Deterioration of the sheath by crystallisation caused by vibration.
(3) Damage to the lead sheath caused by the raw-hide or other slings employed for suspension of the cable.
(4) Damage caused by fire, gunshot, stonethrowing, etc.

Experience in this country generally was that lead-covered cable, suspended overhead in industrial neighbourhoods, had a

comparatively short life, and the British Post Office has not adopted the practice to any material extent.

The ideas originated, and the experiments and trials made, from time to time, for the purpose of determining the most suitable material for employment in the manufacture of insulators, for the support of open wires, and the most effective design, have been innumerable. It is therefore not intended, nor, in fact, is it possible, to refer to them all.

From the time of Mr. Cooke's first open wire line system, numerous substances have been suggested and placed under trial. Insulators of dry varnished wood, indurated caoutchouc, gutta percha, various prepared compounds, glass, stone or earthenware and porcelain have all been tried with varying results.

At one time in the history of the telegraph before the telephone appeared, some insulators were protected by a hood of ordinary or malleable cast iron. They were fixed direct to the supporting pole either by the hood or by the stalk.

Glass insulators were at one time fairly common, but they disappeared in about 1860. Insulators of stoneware were at one time extensively used and gave good results. They were made of clay combined with flint powder (silica) and felspathic minerals, and, in some cases, cement stone or chalk was added to furnish lime. Formerly salt glaze was always employed, but glaze made of flint, decomposed granite, etc., was used at a later date, its composition varying considerably with different manufacturers.

At the time the telephone was invented, insulators of both earthenware and porcelain were universally used and such insulators were therefore commonly adopted. Ultimately an insulator designed by Mr. John Henry Cordeaux of the Postal Telegraph Department, formerly of the Electric and International Telegraph Company, was adopted as standard by the British Post Office, and brought into universal use for telegraph purposes throughout the United Kingdom. Modern insulators for telephone, as well as for telegraph purposes, have for the most part been derived from, or are modifications of, the well-known Cordeaux insulator.

Insulators of innumerable types, each claiming some special advantage or feature for the fulfilment of some particular

condition have from time to time been produced. A few only of the various forms of insulator used in this country for telephone purposes are typified in Figs. 143 and 144.

One of the earliest types of insulator utilised was that known as the "shackle," and for some years the shackle insulator was the one most extensively used. It is illustrated in Fig. 143. In London, it was employed for some years almost exclusively, and the manner in which it was used for the support of wires may be seen from Figs. 23 and 145, which show two overhead structures in London as they appeared in about 1884. These insulators were made

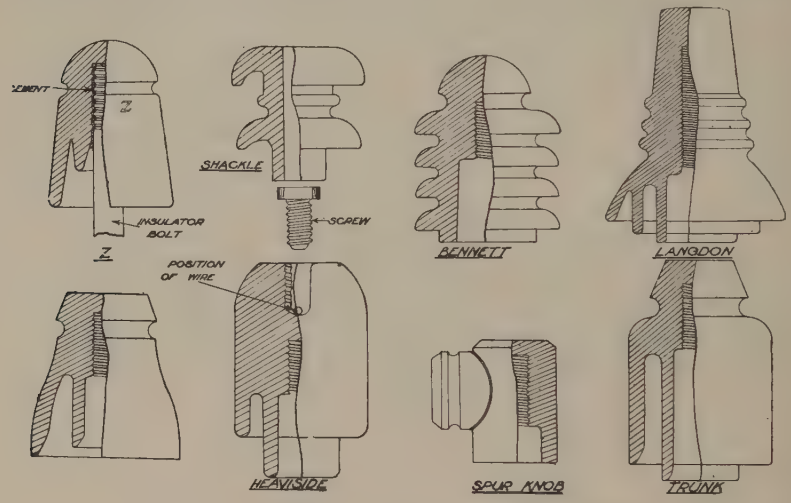

FIG. 143.—Examples of various types of insulators.

both of stoneware and of porcelain, but their insulating properties were not of a very high order. It was not until 1889 that the systematic replacement of shackle insulators by insulators of the upright type was commenced in London.

Amongst the interesting exhibits on view at the Science Museum at South Kensington, London (see Appendix E), are a number of insulators of various types. Amongst these are samples of the earliest insulators used for telegraphic purposes by Sir W. F. Cooke as follows :—

(*a*) Iron wire and (*b*) three-strand copper wire both passing through Cooke's original goose-quill insulators, used on the line between Paddington and West Drayton.

(*c*) Cooke and Wheatstone's original ring insulator of 1840.

(*d*) Double cone insulator, the original form of 1845.

(*e*) Double shed insulator, 1847, in which the hook that carries the line wire was insulated by mastic cement in a cavity at the top of the insulator.

(*f*) Split form of double cone insulator used in connection with the replacement of broken wires.

The use of cross arms, a familiar fitting to the telephone engineer to-day, was not at first general. In London, Birmingham and some other towns they were conspicuous by their absence, the wires being made off on shackle insulators affixed

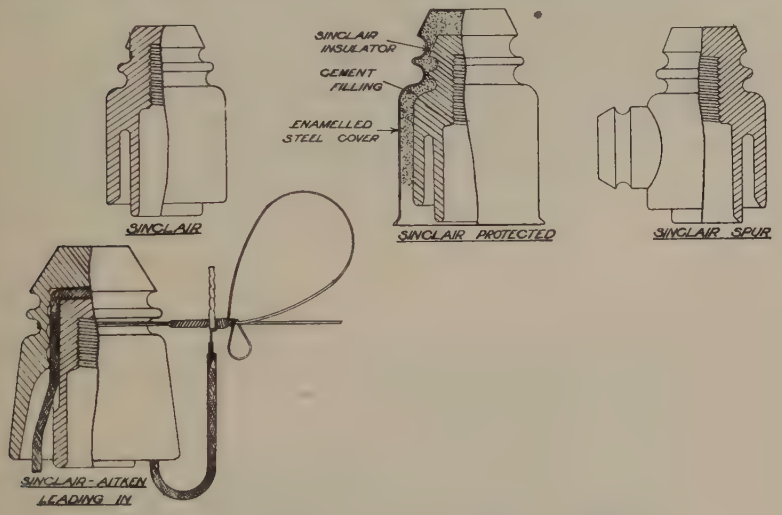

FIG. 144.—Examples of various types of insulators.

directly to the vertical members of the supporting structure. The arrangement of the wires was therefore in vertically disposed rows of from twenty to thirty wires each and the carrying capacity of the supporting structure was thus seriously limited. Examples of roof structures fitted up in this manner are shown in Figs. 23 and 145.

In Glasgow, Manchester and most other provincial towns the form of overhouse construction adopted at an early date involved the use of cross arms, in the manner now employed, affixed to wooden or iron roof poles; the number of uprights and the length and number of the cross arms was proportioned according to the total number of wires to be accommodated. Shackle insulators

were in some cases attached to the arms, but upright insulators affixed in the same manner as to-day quickly displaced them. The eight-wire arm, now a standard fitting for carrying subscribers' lines in this country, was introduced first in the district operated by the Northern District Telephone Company by Mr. C. B. Clay, the general manager, after a visit to the United States, where long arms supporting as many as ten wires were then in use.

In connection with early telephone line construction in this country, the following opinion, expressed by Mr. Thomas D. Lockwood, in a paper read before the American Institute of Electrical Engineers in New York on October 15th, 1889, entitled "Telephony in England and France," after a tour of inspection of the telephone systems of those countries, is of interest :—

"As to electrical construction outside I may say, without hesitation, that the average is far above ours whether telegraphic, telephonic or otherwise. The poles are no longer than are necessary, are uniformly well trimmed and painted and, above all, are well stayed." . . . "In Sunderland only and the other towns where the Northern District Telephone Company holds sway, are to be found long cross arms à la American, the idea having been imported by Mr. Clay who visited the United States a year or two ago, and who is a manager of the most progressive type."

Before the use of underground cables became general, and in those cases where, for any reason, the provision of underground cables was impracticable, the design and construction of suitable structures for the support of the large number of overhead wires and cables required was a matter of considerable importance, and much ingenuity was displayed in designing structures specially adapted to the form of the building upon which they were to be erected. The problem of supporting masses of wires and cables incoming at large exchanges presented special difficulty; in most cases the earlier exchanges were accommodated in buildings not specially erected, but adapted for the purpose, and it was not unusual that structural alterations were necessary in order to give stable support to the superstructure required to carry the overhead wires. Such elaborate overhead arrangements are now no longer necessary owing to the extensive use made of underground cables. In many present-

FIG. 145.—The United Telephone Company's Derrick, Cornhill, London, showing method adopted for supporting overhead line wires.

(From a photograph loaned by Mr. Alfred Perkins.)

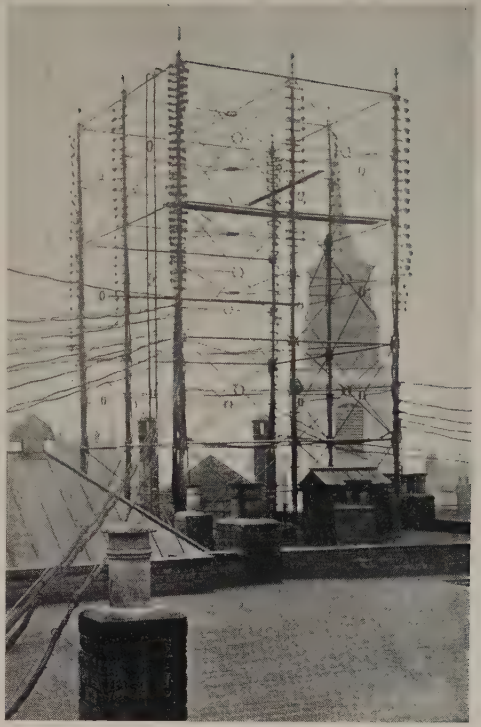

FIG. 146.—Roof Structure, The London and Globe Telephone and Maintenance Company's Exchange, Basinghall Street, London, E.C.

(From a photograph loaned by the late Mr. J. W. Ullett.)

[To face page 428.

FIG. 147.—Wooden Roof Structure for support of Overhead Wires, Sunderland Telephone Exchange.

(From a photograph by Mr. J. Bruce.)

FIG. 148.—Angle Iron Derrick for support of Overhead Wires, Sheffield, 1891.

(From a photograph by Mr. E. J. Johnson.)

[*To face page* 429.

day exchanges the whole of the wires are led in underground, and the immense overhead structures which invariably surmounted the older exchanges, and gave an indication of the purpose served by the building, are no longer necessary.

A number of interesting photographs of structures of different design, employed to give support to the overhead wires and cables entering exchanges at various places in the country, have been collected by the author from time to time, and some of the more interesting are included as illustrations in this volume.

Fig. 24 is from a photograph taken, before any wires were affixed, of an angle-iron derrick designed by Mr. Tomlinson for erection upon certain of the roofs in the City of London. Its use was not confined to leading in at exchanges, and a number of structures of this design known to the staff as "Ironclads" were provided at various places. The example in question was erected at Chancery Lane, the photograph being kindly supplied by Mr. Alfred Perkins, who was also the photographer.

A square derrick of eight tubular iron poles, with suitable braces, erected upon the London and Globe Telephone and Maintenance Company's exchange building, in Basinghall Street, London, E.C., is illustrated in Fig. 146. It will be observed that cross arms were not used. The photograph was taken about 1884.

The subject of the illustration in Fig. 147 was erected in 1888 at a cost of £600 on the roof of the Sunderland Telephone Exchange. The uprights were of pitch pine and the arms, each bored to accommodate 24 wires, were of oak. Its weight was approximately 45 tons, and it was designed to carry up to 1600 wires. Each upright was 40 feet in height and the flagstaff was of equal length. This standard is still in existence.

A unique example of a roof structure of peculiar design is given in Fig. 80. It was designed by and erected under the superintendence of Mr. Alfred Perkins in 1893 upon a building in Lime Street, London, in which the National Telephone Company's Avenue Exchange was housed. It was octagonal in shape, and consisted of 39 tubular iron poles, braced together with iron arms, and securely stayed to the walls of the building. In circumference it was 90 feet, and it was capable of carrying 6000 wires in addition to aërial cables.

An 85 foot angle-iron derrick situated behind the National

Telephone Company's exchange in Commercial Street, Sheffield, is illustrated in Fig. 148. It was erected in 1891–1892 and was capable of accommodating upwards of 1000 wires. The boxing in the centre was for conveying the leading-in wires, of single vulcanised india-rubber, from the overhead wires to the wooden test-house, seen on the second tier of the derrick. The wires thence passed into the exchange test-room, situated within the building on the left hand side.

Fig. 149 shows the neat standard erected in 1894 upon the National Telephone Company's exchange in Market Street, Aberdeen.

Present day telephone engineers who are personally unacquainted with the conditions which obtained in the early stages of telephone development in this country, when single lines with earth return were the rule rather than the exception, and the metallic circuit was practically unknown, may be surprised to learn that the substitution of the earth return by a second wire was actually the subject of a patent. The Patent Office records show that in Specification No. 4341, dated November 20th, 1877, A. G. Bell provided for the employment of a return wire in conjunction with the ordinary line wire, instead of utilising the earth as return. The intention was to prevent the current in the conducting wire of the electric telephone described in Specification No. 4765 of 1876 from being affected by those passing in neighbouring wires.

The well-known system of twisting or rotating two overhead wires forming a metallic circuit, for the purpose of eliminating inductive disturbance in telephone loops, has been practised in this country almost universally since metallic circuits were first employed, but the origin of the method appears to be little known.

On July 1st, 1880, a Provisional Specification for Improvements in the Method of Constructing Telegraphic, Telephonic, and other Wires, which clearly embodied the twist system, was left at the British Patent Office. The Letters Patent was filed in the names of Charles Moseley, William Fereday Bottomley and William Edwin Heys, all of Manchester, and was numbered 2690. The Final Specification describes in detail the methods of construction patented and was dated December 31st, 1880, the stated object of the invention being " to diminish or prevent

the results of inductive action." The system was made applicable to both loop and single wire earth return circuits, and was adopted by Mr. Charles Moseley between Manchester and Oldham.

The three gentlemen named were not, however, the first to announce the utility of the method, although they may have originated the idea independently of others. In the discussion which followed a paper entitled "The Origin and Development of the Telephone Switchboard," read by Mr. J. E. Kingsbury before the Institution of Electrical Engineers on January 24th, 1895, Mr. J. G. Lorrain makes reference to the fact that, in September or October 1879, he erected a number of lines on the twist system in Edinburgh, and that he received the idea from Mr. J. D. Tracy, an American, who informed Mr. Lorrain that the lines of an American telephone system with which he had been associated were erected on this plan.

The credit for the introduction of the twisted pair rightly belongs, however, to Professor Hughes. In the course of a speech, delivered at the National Telephone Company's dinner on March 15th, 1895, Professor Hughes is reported in *The Electrician* for March 22nd, 1895, to have said :—

"Another discovery which I made in the continuance of my researches which is now of the highest utility to far distant telephony, was the use of twisted wires, or wires so arranged upon their insulators that the whole line should gradually revolve on its axis so as to prevent induction from other independent wires. This was freely given to the world in my paper read before the Society of Telegraph Engineers on March 12th, 1879, and fully illustrated by engravings in *Engineering* of the same week. In order to understand this I will quote a single paragraph from this paper: 'If two ordinary aërial lines are thus used, they should have the twist given to these wires by changing their position relative to other wires from vertical to horizontal at each pole. Thus if we had two lines A and B, they should have their four relative positions repeated as often as possible, viz. A B, then $\frac{B}{A}$, then B A, and $\frac{A}{B}$.' This is the system employed by the telephone line between London and Paris and, in fact, upon all successful long-distance telephone lines throughout the world, so I think it is only fair that it should be known that I discovered and published this long before long-distance telephony was ever brought into use."

The methods employed for jointing open line wire have been numerous and the present methods are well known. The popular Britannia joint was originated by Mr. Edwin Clark. In the Science Museum at South Kensington, London, one or two examples of very old line joints are preserved (see Appendix E).

In 1905 consideration was given by the National Telephone Company's engineers to the feasibility of successfully introducing into this country the M'Intire sleeve joint for the jointing of open wires. This joint was already popular in America and its adaptability to American requirements had been satisfactorily demonstrated, but doubt was felt as to whether the climatic and other conditions peculiar to this country would permit of its successful use here. The economical aspects were fairly clear, and the savings secured by its use could be estimated with reasonable accuracy, but it remained to be proved whether in all respects the twisted sleeve joint would be satisfactory in actual practice. In order to demonstrate its adaptability to British requirements, it was brought into practical experimental use in several large centres, and after extended trial the reports received were so favourable as to justify its universal adoption; consequently soldering, with its attendant encumbrances, was abandoned, and sleeve joints became universal.

The advantages derived were :—

(*a*) Reduction in quantity of wire made scrap in jointing.
(*b*) Reduction in labour per joint.
(*c*) Dead weight and value of tools and appliances to be carried for jointing purposes greatly reduced.
(*d*) Deleterious effects of cold soldering avoided.
(*e*) Faultsmen enabled permanently to restore broken connections immediately and unaided.
(*f*) Fuel not necessary and risk of fire avoided.

The introduction and rapid growth of telephony soon led to a greatly increased demand for wood poles as supports for wires. Creosoted poles of red fir, imported chiefly from Norway and Sweden, were in common use for telegraph purposes and poles of similar class were first employed generally for telephone purposes. Home-grown and imported larch poles also were used to a limited extent. Pitch pine, chiefly imported from the Eastern States of North America, has also been used for

telephone poles in this country; pitch pine withstands satisfactorily the diseases to which timber exposed to climatic conditions is susceptible, but its high cost greatly restricted its use. In various parts of the country pitch pine poles for telephone purposes, usually square, were not uncommon; in some places huge masts of pitch pine, sometimes composed of as many as three or four pieces carefully spliced together, and elaborately stiffened and stayed, eighty or ninety feet high, were employed. Pitch pine was also commonly employed in some towns for roof poles and structures, but for roof work timber was soon displaced by iron.

The rapid decay to which raw or even well-seasoned timber for telegraph and telephone poles was subject was a serious disadvantage. It was also subject to injury more or less serious, but nevertheless of limited extent, by the ravages of woodpeckers, also fossorial wasps and other wood-boring insects. Rot is, however, the chief enemy of timber, and arises from the destructive action of a certain class of fungi, termed "saprophytes," which thrives under certain natural conditions. The question of the arrest of rot in timber received early consideration, and numerous measures for the preservation of timber for use in exposed situations have been suggested and tried with varying results.

Long before the reasons for decay of timber were as thoroughly understood as they are to-day, it was fully appreciated that well-seasoned timber had a much longer life than that used in the green state, and it was also discovered that decay might be retarded by treatment of the timber with certain compounds.

Numerous processes have been invented for treatment of timber for the purpose of prolonging its life. The process of creosoting, now the method universally adopted in this country for the preservation of telegraph and telephone poles, as well as timber for other purposes, in situations exposed to the weather, may be said to have originated in 1838. In July of that year, Mr. John Bethell introduced and patented the process of creosoting, and its practical application may therefore be regarded as due to him. Creosote is one of the numerous products of the distillation of coal tar, a by-product of coal gas manufacture. Numerous other derivatives of tar, known under various names, are now available for treatment of timber.

Briefly the creosoting process consists of first subjecting well-seasoned poles, contained in large air-tight cylinders, to a vacuum of about 20 lb. per square inch, in order to extract air from the substance of the timber; creosote is then admitted and maintained at a pressure of from 80 to 100 lb., depending upon the class of timber, until the requisite amount of oil has been absorbed. Twelve pounds of creosote per square foot of timber under treatment is generally regarded as sufficient, and from two to four hours are occupied in the operation.

In 1848, 318 Norwegian poles creosoted by Mr. John Bethell were erected between Fareham and Portsmouth.

There are modifications of the method referred to; one of them, known as the Boulton process, was devised for treatment of green timber, for the purpose of avoiding lengthy preliminary seasoning, a process which, to be successful, requires a period of from six to nine months.

Another modification of the creosoting process is a German patent, introduced about ten years ago, and is known as the Ruping process; its chief claim is an economy in creosote, brought about, without detriment to the life of the timber, by extraction of a proportion of the creosote immediately after injection, an operation aided by the application of vacuum. Approximately 50 per cent. of the creosote intially injected is recoverable in the Ruping process, and the prepared pole is thus considerably diminished in weight. A further advantage of the Ruping process is that poles so treated are more suitable for painting.

The life of a creosoted telephone pole depends very largely upon the thoroughness of the creosoting process.

Impregnation by solutions of metallic salts has also been employed for the preservation of timber. In the year creosoting was introduced by Mr. John Bethell, an eventful year in so far as the invention of processes for timber preservation was concerned, three other methods, in which chemical salts were used, were introduced. The first of these, known as "Kyanising," a process due to Mr. J. H. Kyan, involved treatment of the timber with corrosive sublimate, a compound chemically known as mercuric chloride, a violent poison possessing strong antiseptic properties.

Sir William Burnett devised the process known as "Burnettis-

ing," dependent upon the use of a solution of zinc chloride. Poles used for a telegraph line erected between London, Southampton and Gosport, in 1844, were of the best memel timber preserved by the Burnettising process. This process was formerly used in this country for poles finally to be painted, but it has now been discarded in favour of the Ruping process. Sulphate of copper is another metallic salt used for preservative purposes. The process was introduced by Mr. J. J. Lloyd Marjary in 1838 and was termed "Marjarysing."

None of the last three mentioned methods have been used in this country to any extent comparable with that of creosoting, but Burnettising has been somewhat extensively used in the United States.

The author is indebted to Messrs. Armstrong, Addison and Company, the well-known timber merchants and preservers, of Sunderland, for information relative to the early use and preservation of timber.

For further information respecting the usage and preservation of timber for telephone poles, reference should be made to interesting articles in the *Post Office Electrical Engineers' Journal* for October 1910 and January 1912 by A. O. Gibbon and W. H. Matthews, B.Sc., respectively, entitled "The Telegraph Pole" and "The Decay and Preservation of Timber."

The following extract from Mr. John Christie Douglas's "Manual of Telegraph Construction," published in 1877, gives some information of interest respecting preservative methods as they were regarded at that time :—

"To protect wood from dry rot and the attacks of insects, it is injected (1) with poisonous metallic salts, forming insoluble compounds with the constituents of the timber; or (2) firstly with one salt, and secondly with another, that by chemical reaction an insoluble salt may be deposited in the timber; or (3) with an antiseptic, which at once keeps away insects and preserves the timber. Of the metallic salts, the sulphates of iron and copper, bichloride of mercury, and chloride of zinc have been successfully applied; but these salts are gradually removed by the continued action of water. Injection with sulphate of copper is applied to telegraph poles in France by Dr. Boucherie, and it increases greatly their durability; small objects, as cords, etc., are prepared by mere soaking. Wood in large pieces, some time after felling, is placed in a closed

vessel, subjected firstly to a current of steam; the vessel is then exhausted, and the solution allowed to enter and penetrate the wood. The method proposed by the inventor and most generally applied in France is, to inject the wood as soon as possible after felling. A cap is fitted to one end of the log, this end is placed 3 feet higher than the other end, the solution is admitted to the cap by a tube, and the pressure is obtained by raising the vessel containing the solution on a scaffold 23 to 26 feet high; the sap is driven out and the solution takes its place. The best strength for the solution is 1 part by weight of the salt to 100 parts of water, and ·33 lb. of the solid salt is sufficient per cubic foot. The advantages of this process are its cheapness and simplicity; the trees may be injected where felled; three days is the average time required to inject a 25 feet pole. The most successful process is Bethell's, in which the timber is saturated with creosote. The wood is enclosed in hermetically closed vessels, and the creosote is injected as described above in the case of sulphate of copper. The pressure used ranges from 5 to 10 atmospheres—the nearer the latter figure the better. The inventor considered 7 lb. of creosote per cubic foot sufficient, but this depends on the kinds of wood to be injected; for marine work 10 lb. is considered sufficient, and 12 lb. has been required by some engineers; in hard woods it is sometimes difficult to inject more than 2 or 3 lb. This process is esteemed most highly of all processes for preserving wood, which it protects against white ants, dry rot and marine worms. Telegraph poles, properly injected, have been found well preserved after standing ten to fifteen years in temperate climates. The process has not been fairly tried in tropical climates on telegraph poles; it has been applied to railway sleepers and marine work, but the cases are not similar. It is not known how long the oil would be retained under tropical heat and rains. Injection is of little use unless thoroughly done, whatever liquid is employed; posts prepared with sulphate of copper sometimes decay almost as rapidly as unprepared wood, having been imperfectly prepared, and failure from the same cause is experienced in using Bethell's process. Injection with creosote is coming into more general use for telegraph poles; it has not the simplicity of the Boucherie process, and can only be employed where transport is cheap. A modification of the Boucherie process is employed in Norway; holes are bored in the sap-wood of standing poles and filled with solution or powdered sulphate and stopped."

Modern experience has shown that the average life of creosoted telephone poles is considerably in excess of the fifteen years above mentioned; creosoted poles have frequently been known to attain a life of more than forty years.

Water is the cause of many of the troubles of the electrical engineer, and the telephone engineer appears to be even less favourably situated in this respect than other members of the electrical profession. Whether it be water in liquid form which has penetrated a dry core cable, or as condensation from the atmosphere disseminated amongst insulated wires or apparatus, its presence is soon made manifest and is generally a source of annoyance and trouble difficult to eradicate. It is, however, in the form of a particular kind of soft, wet, clinging snow, of a certain consistency, that water can in a few hours irretrievably damage the cumulative work of years. On frequent occasions storms of snow have entirely wrecked the overhead line plant in the districts over which they have swept, merely by the accumulated weight of the snow upon the wires. The possibility of damage under these conditions is greatly increased by a fall in temperature after snowfall. A wire of such small dimensions as No. 18 S.W.G. may, in the course of a few hours, be called upon to support, from end to end of a span, a deposit of snow as much as two or three inches in thickness, or break under the strain. The weight imposed by such accumulations upon poles carrying many wires has frequently been the cause of the stoutest poles being uprooted altogether or completely fractured. Even if poles and wires remain actually unbroken after heavy falls of wet snow, serious injury may be caused by the severe strain imposed and deflected poles, ruptured stays and disturbed regulation of wires is a common result; complete overhaul, frequently at heavy expense, is always necessary in such cases.

On numerous occasions in the history of the telephone in this country serious dislocation of the telephone service has been caused by heavy falls of snow, and the resources of the telephone administrations have been taxed to the utmost in effecting the necessary repairs and restoring the service with dispatch. Financial loss due to extensive damage by snowstorm is an item telephone administrations must be prepared for.

One of the earliest cases on record of disaster to overhead telephone plant, brought about by snowstorm, occurred on Christmas Day in the year 1886, when the United Telephone Company's London telephone system suffered severely. The effect of this storm was the first serious indication of the stupendous havoc which a severe snowstorm could wreak on

the open line plant of a telephone system; also of the serious interference to telephone communication which follows, and of the heavy expense needful to restore communication, and the plant to an efficient state of repair. Soft snow fell for some hours and accumulated on the overhead wires in the way best known to telephone engineers. Unfortunately, it was followed by frost, with the now well-known result following such a combination, and the overhead plant was literally pulled to pieces. Wires were down by the hundreds, iron roof poles were bent, buckled and broken or rooted bodily from their foundations. Two immense and heavy derricks weighing many tons, one in Mincing Lane and the other in Oxford Court, Cannon Street, were torn from the buildings supporting them and fell into the streets below. The telephone service was dislocated for many weeks and the total cost to the United Company amounted to as much as £30,000. This great storm brought down the bulk of the overhead wires in London, together with the standards and poles which supported them. It was considered that a contributory cause of the excessive demolition of supports was the heavy iron line wire they carried and consequently, bronze wire was introduced in anticipation that, when subjected to similar storms, the lighter bronze wire would break, leaving the supporting roof poles standing. This supposition, however, was never realised, as advantage was taken of the decrease in weight of wire in another direction, namely, to use the same supports for a larger number of wires than was practicable with iron.

The most extensive damage caused by gale to telephone line plant in the United Kingdom occurred on March 27th, 1916. This gale came from the north-east and expended its greatest violence upon some of the Midland counties. It was accompanied by heavy falls of snow and freezing rain, which, besides blocking up the roads to a depth of several feet, clung several inches thick to the wires, considerably increasing the weight to be supported and the surface area exposed to wind pressure. Almost every telephone line crossing the affected belt of territory from north to south was wrecked and many poles and fittings were smashed. Poles to the number of 2150 were fractured, 6050 were uprooted and 33,300 blown over. The erection of 41,500 poles and 17,000 miles of new wire was involved. The repair of the damage would have taxed to the utmost the resources

FIG. 149.—Roof Structure for support of Overhead Wires, Telephone Exchange, Market Street, Aberdeen, 1894.

(*From a photograph loaned by Mr. J. H. Storrie.*)

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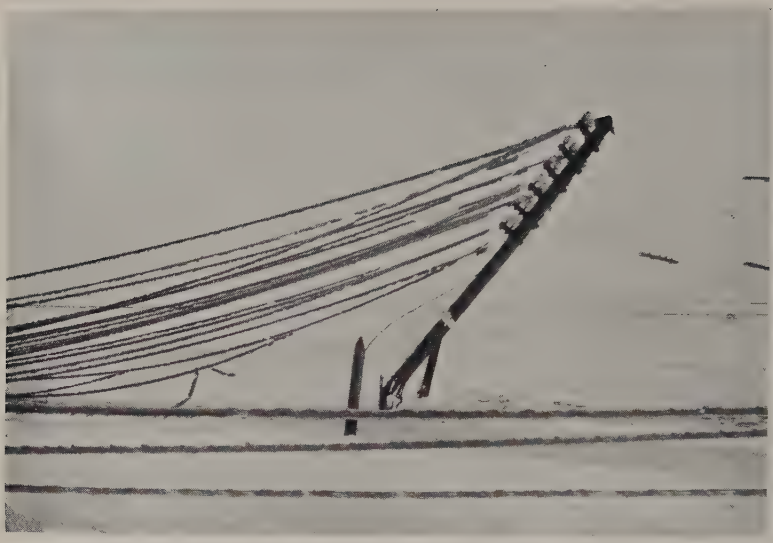

FIG. 150.—Snowstorm Damage in West Yorkshire, 1916.
(From a photograph by Mr. F. W. Best.)

FIG. 151.—Snowstorm Damage near Dunford Bridge, 1916.
(From a photograph by Mr. F. W. Best. By permission of the Editor of the Post Office Electrical Engineers' Journal.)

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of the Post Office Engineering Department in normal times, but at this period about half the staff were on war service, and although the aid of the military authorities was invoked, the work of repair was unavoidably protracted over many months.

Some typical examples of snowstorm damage from photographs by Mr. F. W. Best are illustrated in Figs. 150 and 151. The latter is published by permission of the Editor of the *Post Office Electrical Engineers' Journal.*

Opinions have sometimes been expressed that telephone overhead plant should be constructed in such a manner as to withstand satisfactorily the stresses caused by climatic influences such as those referred to, but statements to that effect are indicative of complete ignorance of the controlling factors.

Much as the telegraph and telephone services have been criticised, it is a well-recognised and undisputed fact that the construction of the Post Office telegraph and telephone trunk open wire line system is the finest in the world. For stability and sound construction, it stands unrivalled and on several occasions has been the admiration of American engineers during visits paid to this country.

Typical trunk line construction of the British Post Office is illustrated in Figs. 166 and 167. In the former is shown an "A" pole line, a type of construction very popular in 1900. Fig. 167 represents a pole of the "H" type, of more recent date.

Since the introduction of insulators of the Cordeaux type and of hard drawn copper and bronze wire, no very drastic changes have taken place in British open wire line practice; the modifications introduced have been of minor consequence only.

The difficulties of maintaining in this country, at a satisfactory figure, the insulation of long open wire lines are not inconsiderable, and possibly are such as are not encountered in countries enjoying a drier climate. The condensation which results from the humid atmosphere which is a feature of these islands, particularly at those periods of the year and in those parts of the country subject to heavy damp mists and sea frets, is responsible for serious loss of insulation.

In the United Kingdom local amenities are very jealously guarded, and the liberty enjoyed in America in respect of the erection of pole lines and the apparent disregard for appearances

are absent in this country. Local authorities frequently have opposed, on various grounds, proposals for the erection of poles on public thoroughfares, adding to the difficulties of administration of the telephone service.

The extended use which, in late years particularly, has been made of underground cable for subscribers' circuits has considerably reduced the amount of overhead wire which at one time existed and, owing to the introduction of modern methods of distribution, long and heavy lines, supporting large numbers of wires for subscribers' circuits, are now the exception rather than the rule. There is even a tendency for the long overhead lines of heavy copper conductors which for many years have formed the means of telephonic communication over long distances in this country to disappear; the application of line loading and the invention of the valve amplifier, applied in the introduction of an effective telephone repeater, has now made possible the interchange of speech over the longest distances exclusively by means of subterranean conductors. When the scheme for the provision of an underground trunk line system for the United Kingdom, now in process of construction, fructifies, the necessity for the existence of long distance open wire lines will largely, if not wholly, disappear, and it is anticipated that a long distance telephone system immune from the interruptions and disturbances due to climatic and other influences, inseparable even from the best constructed overhead systems, will eventually be established.

FIG. 152.—Cross-armed Distribution Pole with Cablehead terminating 77 pair 20 lb. cable, 1897.
(From a photograph by the author.)

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FIG. 153.—Erecting a 75-foot pole in a difficult position, London.
(From a photograph supplied by Mr. J. L. Brown.)

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CHAPTER XVII

TRANSMISSION

1. *Transmitters and Receivers*

From the inception of telephony the question of effecting improvement in the transmission of speech by electrical means has been ever to the fore, and the attention of numerous scientists and inventors has constantly been directed towards the accomplishment of this end. Apart from the economic aspect of the question, the problem has been, first to increase the distance over which telephonic speech is commercially possible, and secondly, to increase the intensity and improve the clarity of the speech received. The telephone apparatus which, at first, appeared to be most directly concerned was obviously the transmitter and the receiver, and therefore it was but natural that first attention should be given to the possibilities presented by modification of known types, or by the invention of entirely new patterns, of these two essential pieces of apparatus.

The various stages of development through which the telephone receiver and transmitter have progressed since their inception is a matter not necessarily associated with the subject of telephone transmission, yet, in the main, the successive improvements made in these two essential instruments were for the purpose of effecting improvements in the quality of transmitted speech, and therefore it will not be out of place to treat of the development of the telephone transmitter and receiver under the present head.

The original Bell telephone was sensitive enough, but it soon showed its weakness and unsuitability when used as a transmitter. When the early single pole Bell telephones were used as receiver and transmitter, speech was too weak to be regarded as satis factory if the total resistance of the circuit exceeded something of the order of 2500 ohms, even with a metallic circuit operating under ideal conditions.

With the advent of the Edison graphite transmitter, and the Blake transmitter which quickly followed it, Bell's magneto telephone was entirely discarded as a transmitter, and the introduction of the battery instrument considerably improved the efficiency of transmission, and greatly increased the distance over which speech was practicable. The Bell single pole receiver and the Blake transmitter were used successfully in combination, and gave excellent results for many years.

In those early days it, no doubt, seemed a very sensible and obvious proposition that an increase of battery power applied to any moderately successful transmitter should have the effect of increasing the loudness or intensity of speech received, but it was soon found that there existed a very marked limit to the voltage which with impunity could be applied to any transmitter, and that, instead of securing improvement by increasing the number of cells, the reverse was actually the case. A comparatively small increase in voltage was sufficient to cause such objectionable jarring, singing and crackling noises that speech was almost obliterated. It was thus appreciated, at a very early date, that the sensitivity of a transmitting device practically disappeared, when the voltage applied exceeded a certain fixed limit, and that there was but little prospect of any considerable improvement being effected by that means.

Telephone receivers of innumerable designs have been produced since the invention was first announced. Despite all the attention which has been bestowed upon it the principle adopted by its inventor, Professor Graham Bell, has not been departed from, and his receiver has not lent itself to very far reaching modification or improvement. The receiver now in common use is substantially the same as Bell's improved telephone.

The development of the Bell receiver is very simply indicated in Fig. 154.

The first drawing (*a*) in the illustration, is a longitudinal section of Bell's wooden case telephone in which a single solid bar magnet of steel was employed. The second drawing (*b*) illustrates the form of single pole receiver manufactured for the United Telephone Company and later the National Telephone Company. In this type, the solid steel bar magnet gave place to a four-piece laminated steel bar magnet, provided with a soft iron pole piece supporting the receiver coil, wound upon a boxwood bobbin, all enclosed within

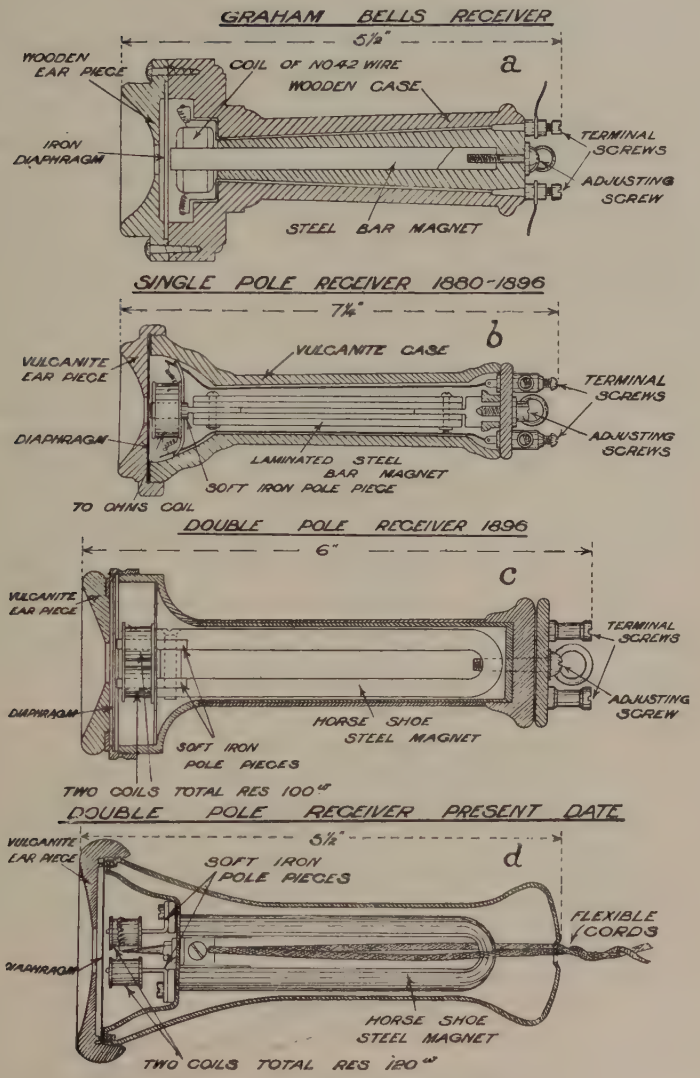

FIG. 154.—Development of the Receiver.

(*a*) Bell's wooden case telephone.
(*b*) Single pole receiver in ebonite case.
(*c*) Double pole receiver.
(*d*) Modern bi-polar receiver.

a vulcanite case. The coil was wound to a resistance of 70 ohms, and an adjusting screw was provided for regulating the separating distance between the diaphragm and the pole piece. This type of receiver was exceedingly popular, and, in conjunction with Blake transmitters, many thousands were in use up to about 1890, and for a few years after. From this time commenced their replacement by the improved type of receiver next illustrated at (*c*) in the same figure. The principal improvement made in this receiver was that a long steel bar magnet of elongated U-shape was used in place of the straight bar magnet. Each pole was fitted with a soft iron pole piece, carrying a coil of wire, the resistance of the two coils amounting to 100 ohms. The double pole form of instrument illustrated was for many years used extensively by the National Telephone Company. The illustration is typical of numerous designs available at the time. A later type of receiver differing in minor detail only from the one just mentioned is shown at (*d*) in Fig. 154.

A receiver which, perhaps, is not in the direct line of development of the present day instrument, but which nevertheless was, at one time, extensively used and possessed several distinctive feàtures, was the Gower-Bell receiver. It was the product of F. A. Gower, and was covered by Patent Specifications Nos. 315 and 394, of January 25th and January 30th, respectively, in the year 1879. This receiver is illustrated in Fig. 155, which shows the type adopted by the British Post Office in 1881, and also by several railway companies. It was said to be more powerful than the Bell and was of more substantial and heavy construction, being about $4\frac{1}{2}$ inches in diameter. It could not therefore be conveniently held to the ear and, consequently, was permanently mounted within the case of the telephone instrument; for reception purposes, two flexible tubes, provided with ear-pieces, were fitted to it by means of a bifurcating metal tube. The diaphragm, of tinned iron, was clamped between brass rings, and the resistance of the wire on each coil was approximately 100 ohms.

A feature of the early type of Gower instrument, when used both as transmitter and receiver, was an attachment consisting of a flat tube furnished with a vibrating reed, intended to be used for signalling purposes. The reed was caused vigorously to vibrate by blowing into the flexible tube, and corresponding vibrations in the diaphragm were reproduced at the distant end

with sufficient intensity to constitute a calling signal. This reed attachment was the subject of a Patent Specification No. 3892 of October 3rd, 1878, wherein it was claimed, incidentally, that it had the effect of intensifying the power of the articulate sounds transmitted.

Apparently from the Gower receiver were derived the numerous forms of watch receiver ultimately placed on the market. Receivers of this class were commonly used as extra receivers, and on cheaper forms of telephone instrument manufactured for private purposes. They were also much used on public

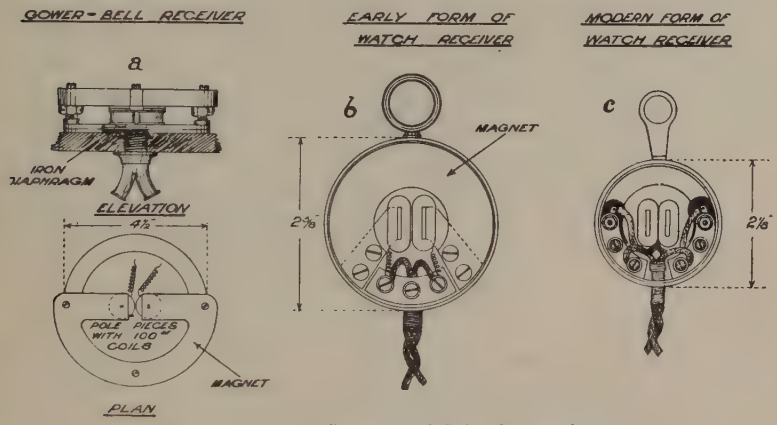

Fig. 155.—Gower and Watch Receivers.
(*a*) Gower receiver.
(*b*) Watch receiver with horseshoe magnet.
(*c*) Watch receiver with ring magnet.

exchange systems, in the hand combination micro telephones which gained such wide popularity, and as operators' head-gear receivers. Types of watch receivers are illustrated in Fig. 155. The first one (*b*) has a magnet similar in form to that of the Gower and in the latter and more modern type (*c*) the magnet is of circular shape.

Photographs of groups of miscellaneous receivers of types now relegated to past history are reproduced in Figs. 156, 157 and 158. They will be described in more detail later.

Unlike the receiver, the microphonic transmitter lent itself readily to experiment, and to the production of different types, in fact the number of different forms of transmitter which have been devised from time to time is legion. The large amount of

inventive genius bestowed upon the telephone transmitting device, for the purpose of producing new or improved types, particularly in the early stages of telephony, is distinctly evidenced in the records of the Patent Office. Although each inventor had some particular idea in mind in designing his instrument, many of them were produced during the period prior to the expiration of the master patents, obviously for the purpose of evading patent rights.

The Edison and Blake transmitters have already been mentioned and illustrated, see Figs. 7 and 12. The former had not a very long life, and, so far as the principal telephone companies were concerned, it gave place to the Blake, which was the first really practical transmitter and which gave admirable service for many years. No transmitter, either before or since, has, perhaps, transmitted speech so faithfully and with greater clarity than the Blake. When adjusted to a nicety, it was a perfect transmitter for short distances, but it could not be adapted satisfactorily for long distance work. Attempts were made to adapt Blake's instrument to a larger battery power than was supplied by the single cell customarily employed, but without success, the addition of even a second cell being sufficient to impair its performance seriously.

Fig. 159 illustrates broadly the development of the telephone transmitter of the Hughes microphone or carbon pencil type, in so far as British productions are concerned. The original form of Hughes' unpatented microphone, the progenitor of the numerous forms of carbon transmitter which followed it, is first shown. The first telephone transmitter of the Hughes microphone type which appears to be recorded in the Patent Office is referred to in Provisional Specification No. 3916 of October 4th, 1878, in the name of C. F. Vasey. As no Final Specification was forthcoming, the patent became void. The Crossley was really the first form of carbon pencil microphone following Professor Hughes' idea to be employed practically as a telephone transmitter in this country. It was invented by Mr. Louis John Crossley, of Halifax, and was protected by British Patent Specification No. 412 of February 1st, 1879. This transmitter was manufactured by Messrs. Blakey and Emmott, electrical engineers, of Halifax. It was largely used for private wire service and early exchange service in Leeds, Halifax, Bradford and the immediate neighbourhood, and was the first instrument to be employed by the Post Office.

FIG. 156.—Group of Twelve Historic Receivers.

(*a*) Ring-magnet watch receiver.
(*b*) Watch receiver.
(*c*) Manchester watch receiver.
(*d*) Original form of Ader receiver.
(*e*) Mahogany-cased single-pole receiver.
(*f*) Sheffield "Potato Masher" receiver.
(*g*) Crossley's receiver.
(*h*) Early form of receiver used in England.
(*j*) Stanhope receiver.
(*k*) The Telephone Company's single-pole receiver.
(*l*) Double-pole receiver.
(*m*) First universal form of double-pole receiver.

(*From a photograph by the author.*)

[*To face page* 446.

FIG. 157.—Group of Early Receivers.

(*a*) Single-pole receiver in mahogany case.
(*b*) Double-pole receiver.
(*c*) Ader receiver.
(*d*) Crossley receiver with ear-piece removed.
(*e*) and (*f*) Sheffield " Potato Masher " receiver.
(*g*) Stanhope receiver.
(*h*) Watch receiver in mahogany case.

(*From a photograph by the author.*)

[*To face back of Fig.* 158.

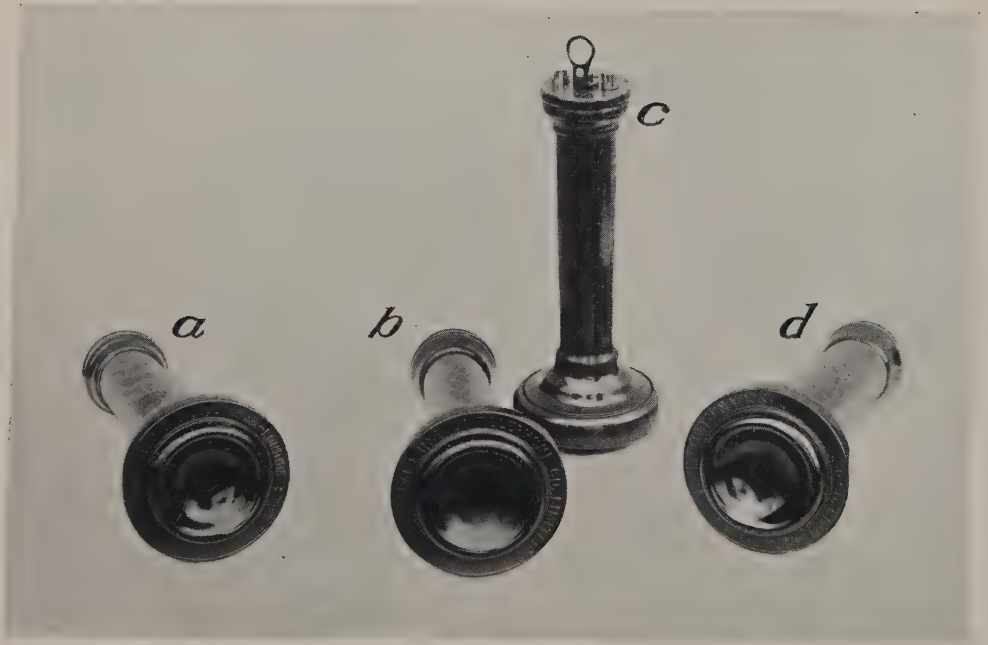

FIG. 158.—Four Historic Telephone Receivers.

(*a*) Single pole. Ear-piece marked The Telephone Company, Ltd.
(*b*) Single pole. Ear-piece marked United Telephone Company, Ltd.
(*c*) Early form of double-pole receiver made in America.
(*d*) Single pole. Ear-piece marked National Telephone Co., Ltd.

(*From a photograph by the author.*)

[*To face page* 447.

The Gower transmitter followed the Crossley and was covered by Patent Specification No. 2610 of June 26th, 1880. It had six pencils arranged as indicated in the illustration. It was employed by the Post Office and by several railway companies generally in association with the Gower receiver in the complete telephone instrument illustrated in Figs 52 and 53.

Mr. W. Johnson, engineer and manager of the Sheffield Telephone Exchange and Electric Lighting Company, devised the carbon pencil transmitter known as the Johnson. It had two pencils arranged as shown in Fig. 159 (*d*). Patent Specification No. 5387

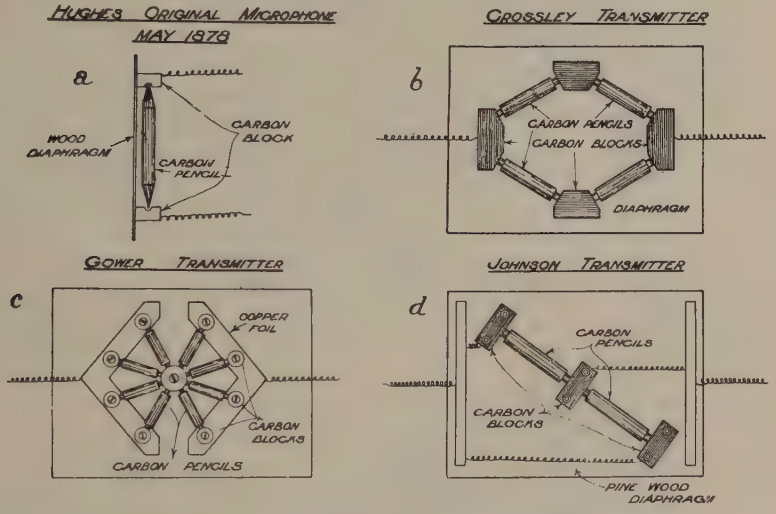

FIG. 159.—Development of the Carbon Pencil Transmitter.
(*a*) Hughes' simple microphone. (*c*) Gower's transmitter.
(*b*) Crossley's transmitter. (*d*) Johnson transmitter.

of December 22nd, 1880, provided for the two electrodes of the transmitter being shunted by a branch circuit of low resistance under a claim that if both the pencil contacts became interrupted the extra induced current in the primary of the receiver passed through the branch circuit, thus preventing sparking. The doubtful utility of this adjunct was demonstrated by the fact that instrument inspectors in Sheffield, where this transmitter was widely used by the Sheffield company, adopted the practice of severing the shunt circuit on the occasion of the first visit paid to the subscribers' premises.

The development of the granular carbon transmitter is illustrated

in Fig. 160. The original Hunnings transmitter, the progenitor of the modern transmitter now in common use all over the world, was invented by the Reverend Henry Hunnings, of Bolton Percy,

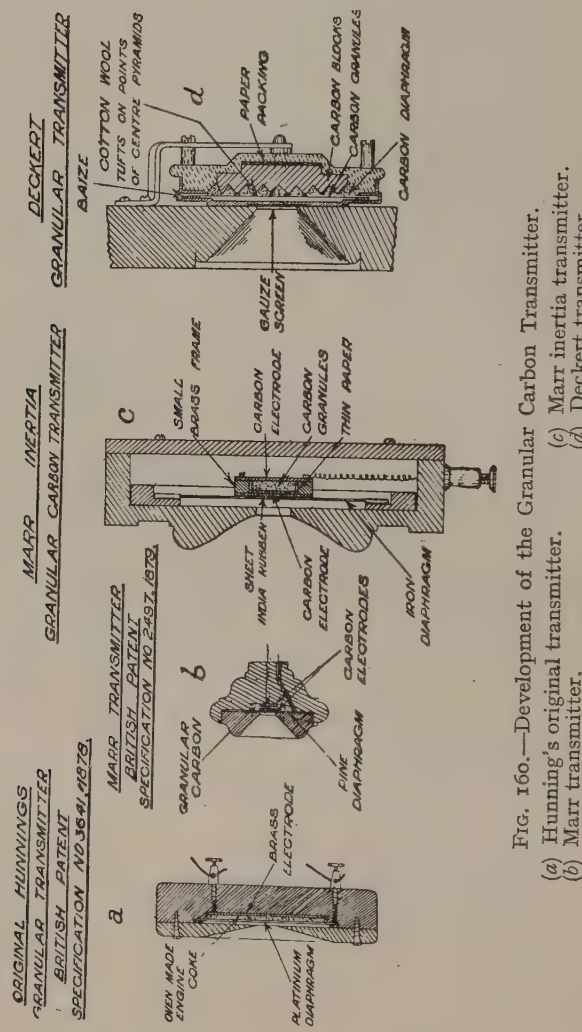

FIG. 160.—Development of the Granular Carbon Transmitter.
(a) Hunning's original transmitter. (c) Marr inertia transmitter.
(b) Marr transmitter. (d) Deckert transmitter.

in Yorkshire. It was covered by British Patent Specification No. 3647 dated September 16th, 1878. The idea of utilising particles of carbon in loosely compacted form between two electrodes, originated by Mr. Hunnings, was not immediately

followed up in such a way as to produce quickly a practical form of instrument.

The satisfactory performance of the Blake transmitter, used almost exclusively for more than ten years, over the comparatively short distances to be covered in this country, probably had something to do with the somewhat tardy development of the granular carbon transmitter. Had the development of long distance service been more rapid, the demand for a more efficient instrument would probably have been greater, and the production of a satisfactory transmitter of the granular type might consequently have been hastened.

Nevertheless, from the date of the Hunnings patent, *i.e.*, September 16th, 1878, until the production of the Deckert transmitter, the first form of granular transmitter to be brought into common use in this country, the attention of various inventors was centred upon the problem, and some twenty British patents were taken out in respect of transmitters of the granular carbon type.

One of the chief difficulties encountered was the tendency exhibited by the carbon particles to consolidate, or "pack" together, and attempts were made to overcome this packing in a variety of ways.

Hunnings' original transmitter had a diaphragm of platinum. Alexander Marr, of Manchester, in Patent No. 2497 of June 21st, 1879, utilised a diaphragm of thin pine wood, with a carbon disc or button affixed to its centre, to form the front or vibratory electrode. Charles Moseley, also of Manchester, who was associated with Marr, in his patent No. 2451 of May 24th, 1882, utilised a diaphragm of ebonite, on the rear of which was mounted one or more cells or shallow boxes to contain the carbon electrodes and granules. Mr. Moseley manufactured transmitters of the granular type employed by the British Post Office prior to the general introduction of the Deckert.

E. Berliner used a horizontal carbon diaphragm, as described in Patent Specification 5276 of April 15th, 1886.

In spite of the skilled attention given to the matter, it was not until the introduction of the improved Hunnings-Cone or Deckert transmitter that instruments of the true granular type came into common use in this country. The Deckert transmitter was of Austrian origin, and was described in British Patent Specifications

11304 and 21565 of July 15th, 1889, and December 9th, 1891, respectively, under the name of its inventor, W. Deckert. It was manufactured by the General Electric Company, and was introduced both by the Post Office in general replacement of the Gower transmitter, and by the National Telephone Co., Ltd., in place of the Blake. Fig. 160 (*d*) is a section of the type adopted by the National Company, and indicates how it was adapted to the old wooden cases which had previously contained instruments of the Blake type.

The granular transmitter thus came into general use in this country. So much more powerful was it than the Blake, that when applied to single earth return circuits the inductive effect was sufficient to cause serious disturbance to neighbouring single lines and its use on earth return circuits had to be abandoned. The National Telephone Company, therefore, continued to employ the Blake transmitter on earth circuit systems only; instruments of the Deckert type were fitted in the old Blake cases at subscribers' premises when the lines were metallic circuited. For operators' breastplate transmitters, and transmitters in combination hand micro telephone sets the Ericcson granular transmitter was adopted by the National Company.

From the Deckert granular transmitter to the present day transmitter of the Hunnings type is not a very far step; comparatively minor improvements of detail only have since been made.

The induction coil plays a most important part in the electrical transmission of speech and has been employed generally, in conjunction with the telephone transmitter, ever since the invention of the first transmitter by Edison. In his Patent Specification No. 2396 of June 15th, 1878, which describes the carbon or graphite transmitter, provision is made for an induction coil, with the primary winding in series with the transmitter, a switch and battery, and the secondary coil in series with the receiver. The application of the induction coil to the telephone transmitter has therefore been attributed to Edison, in addition to the invention of the first practical form of transmitter. Edison was probably oblivious of the fact that Emile Berliner of Boston, who perfected the Blake transmitter, had in a similar manner previously adapted an induction coil to a microphonic transmitter with carbon contacts, for which he secured a patent in America on July 7th,

1877. In Berliner's arrangement, the primary winding of the induction coil was included in circuit with the battery and microphone, and the secondary circuit was in series with the line.

Scattered about the country there are still in existence at the present time examples of different types of telephone receiver, transmitter and other telephonic apparatus which played a part in the provision of telephone service in the early days of the telephone in the United Kingdom. The author has been enabled to get together, for purposes of illustration in this volume, a fairly representative collection of such receivers and transmitters of historic interest. Some of them have been acquired by the author from time to time and others have been presented or loaned to him expressly for the purpose named. They are now in the Museum of the Institution of Electrical Engineers.

Photographs of some of these instruments appear in Figs. 27, 156, 157, 158 and 161.

The author is indebted to the following gentlemen for placing at his disposal the several instruments depicted in these illustrations :—

The late Mr. J. W. Ullett, of Nottingham.
Mr. E. Cox-Walker, of Darlington.
Mr. G. E. Gilpin, of Newcastle-on-Tyne.
Mr. R. W. Jackson, of Newcastle-on-Tyne.
Mr. F. W. Best, of Rochdale.
Mr. F. Barr, of Sheffield.
Mr. Alexander Marr, of Manchester.
Mr. David Moseley, of Manchester.

Fig. 156 is from a photograph of a group of twelve interesting telephone receivers variously used in the earlier days of telephony in this country. In the photograph each receiver is identified by letter. Brief particulars of each instrument are as follow :—

(*a*) This early form of watch receiver was known as the " Ring Magnet Watch Receiver," and was manufactured by the General Electric Company. It measured $2\frac{7}{8}$ inches across and weighed 8 ounces. As the name implies, the magnet was in the form of a ring, the case being constructed wholly of ebonite.

(*b*) Another early form of watch receiver; a drawing of the

same instrument giving details of its construction appears in Fig. 155. Its weight was $9\frac{1}{2}$ ounces and its overall diameter $2\frac{3}{4}$ inches. The case was of nickel plated brass.

(*c*) A small and compact watch receiver known as the "Manchester," another speciality of the General Electric Company, much used at one time for small private installations. Its weight was $5\frac{1}{2}$ ounces and the overall diameter of the metal case was $2\frac{1}{4}$ inches.

(*d*) The original form of Ader receiver, of French make. Its chief features were the large magnet external to the case, which also served as a handle, and a small ring of soft iron let into the metal cover, immediately beneath the ear-piece, for the purpose of increasing the magnetic flux passing through the iron diaphragm. The weight of the instrument was $9\frac{1}{2}$ ounces.

(*e*) One of the earliest receivers manufactured in this country before the introduction of the microphonic transmitter. This receiver was used by Messrs. David Moseley and Sons, of Manchester, and it is believed the specimen in question was manufactured by Messrs. Blakey and Emmott, of Halifax. The case was of polished mahogany and the diaphragm $3\frac{1}{4}$ inches in diameter.

(*f*) Messrs. Tasker, Sons and Co., of Sheffield, at first employed receivers of the type illustrated at *f* in Fig. 156. It was commonly known as the "potato masher," in view of its resemblance to the domestic article of that name then in common use. It was made of mahogany with substantial brass mountings, and receives further mention in Chapter IV. The form of its magnet, only one pole of which was utilised, may be seen at *f* in Fig. 157.

(*g*) This substantially made receiver was devised by Mr. Louis John Crossley, of Halifax, and was protected by British Patent Specification No. 158 of January 14th, 1880. The case of the specimen which is the subject of the illustration is of polished ebony. The special feature of the Crossley receiver was the arrangement of the magnet seen in Fig. 157 at *d*, which shows the instrument with the ear-piece and diaphragm removed. Both poles of the U-shaped magnet projected towards the diaphragm, but only one of them was fitted with a coil of wire. Its total weight was $8\frac{1}{2}$ ounces.

(*h*) Another form of receiver used in the early days of telephony in this country.

(*j*) The Stanhope receiver. Its special feature was the diaphragm, which consisted of parchment in the centre of which a small iron disc was fixed.

(*k*) The single pole receiver adopted for universal use by the Telephone Co., Ltd., in London, is shown at *k* in Fig. 156. It was manufactured in America.

(*l*) Another form of early telephone receiver is illustrated at *l*. Its magnet was not bar-shaped, as might be inferred from the form of the instrument, but was wholly enclosed in the portion of the case which contained the diaphragm; it was U-shaped and was fitted with two pole pieces, both being fitted with a coil of wire.

(*m*) The last illustration, *m*, of Fig. 156 shows the first form of true double pole receiver universally used in this country; an indication of its American origin and manufacture is to be seen in the red band encircling and forming part of the case containing the magnet, which, however, will perhaps not be discernible in the reproduction.

In Fig. 157 the receivers illustrated are as below.

(*a*) Single pole receiver in polished mahogany case, also illustrated in Fig. 156 at *e*.
(*b*) The same receiver illustrated at *l* in Fig. 156.
(*c*) Ader receiver.
(*d*) Crossley receiver with ear-piece removed showing arrangement of magnet; also illustrated in Fig. 156, *g*.
(*e*) and (*f*) Sheffield "potato masher," the latter with ear-piece removed to expose the single pole magnet (which in this specimen has no coil); also illustrated in Fig. 156, *f*.
(*g*) Stanhope receiver, also shown at *j* in Fig. 156.
(*h*) Watch receiver in mahogany case.

The three receivers illustrated at *a*, *b* and *d* in Fig. 158 are of the type which was familiar to most telephone users in this country in the period 1880 to 1895. Their respective ear-pieces are inscribed as follows :—

(*a*) The Telephone Co., Ltd.
(*b*) The United Telephone Co., Ltd.
(*d*) The National Telephone Co., Ltd.

The receiver shown at *c* in the same illustration was the first type of double pole receiver to be brought into common use in this country. It was manufactured in America.

A photograph of a group of nine interesting transmitters, all now relegated to past history, is given in Fig. 161.

(*a*) A transmitter made by the Consolidated Telephone Company described as the "101 Transmitter." It was somewhat similar in type to the "Berthon" transmitter, and consisted essentially of a fixed electrode of carbon provided with a conical cavity, containing a number of carbon pellets, the size of small gun shot; a diaphragm of carbon fixed in front of the cavity kept the pellets in place and formed the front electrode, and was protected by a ferrotype diaphragm.

(*b*) The metal cased Blake transmitter is illustrated at *b*. This instrument was adopted by the United and other telephone administrations in this country for switchboards, in substitution for the larger and more cumbersome wooden-cased Blake. It was suspended from above by means of cords running over pulleys, and provided with counterbalances to facilitate adjustment to any convenient height, and did not so much obstruct the operator's view of, and access to, the multiple jacks, as the wooden-cased instrument.

(*c*) Mr. Alexander Marr's transmitter, covered by British Patent No. 2497 of June 21st, 1879. It was made by Messrs. David Moseley and Sons, of Manchester, and supplied to various railway companies for use in signal boxes in 1880 and 1881.

(*d*) The instrument marked *d* in Fig. 161 is the Hunnings transmitter employed by the London and Globe Telephone and Maintenance Company for their exchange system in London in 1883. This was the instrument which figured so prominently in the famous patent case between the United Telephone Company and Messrs. Harrison, Cox-Walker & Co., of Darlington. It was held in the hand while speaking and was employed without an induction coil.

(*e*) An early form of granular transmitter.

(*f*) The Johnson carbon pencil transmitter invented and patented by Mr. W. Johnson of Tasker, Sons and Company and largely employed by that firm at Sheffield.

(*g*) The illustration *g* in Fig. 161 is not a receiver, as might be presumed owing to its resemblance to the common form of that

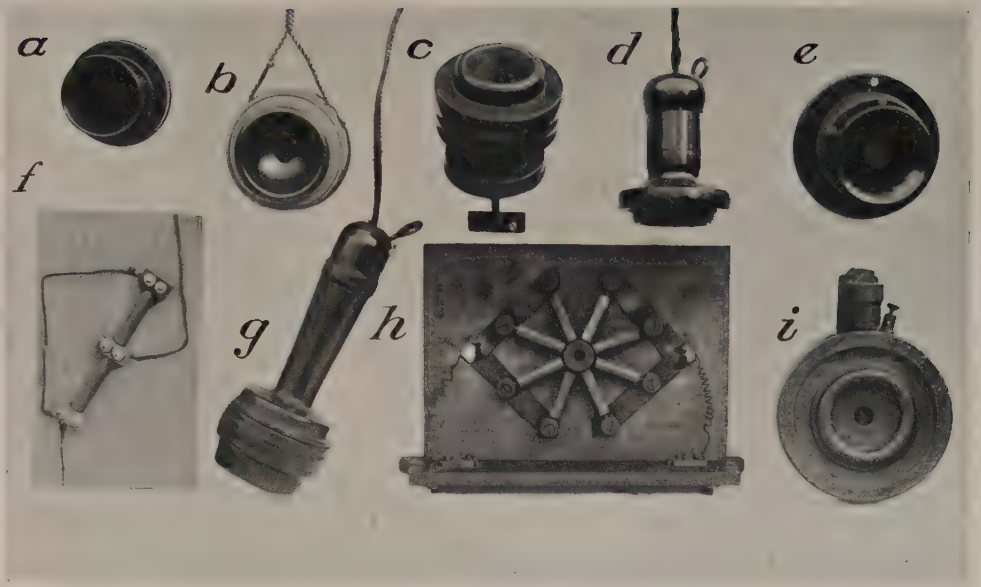

FIG. 161.—Group of Nine Historic Transmitters.

(*a*) " 101 " transmitter.
(*b*) Metal-cased Blake transmitter.
(*c*) Marr transmitter.
(*d*) Early Hunnings transmitter.
(*e*) Early granular transmitter (improved Hunnings).
(*f*) Johnson transmitter.
(*g*) Original Hunnings transmitter made by Harrison, Cox-Walker and Co.
(*h*) Gower transmitter.
(*i*) Marr " Inertia " transmitter.

(*From a photograph by the author.*)

[*To face page* 454.

instrument, but is one of the original Hunnings transmitters made by Messrs. Harrison, Cox-Walker & Co. The case was of polished walnut. The author is indebted to Mr. E. Cox-Walker for the loan of this interesting specimen.

(*h*) A Gower transmitter much used by the Post Office at one time, of which a drawing is given at *c* in Fig. 159.

(*i*) At *i* is shown the original "inertia" transmitter invented by Mr. Alexander Marr, and used by Mr. Charles Moseley for transmitting operatic performances from Manchester theatres as early as 1880.

2. *The Pupin Loading Coil*

So far as the line was concerned, it was generally conceded at an early date that satisfactory telephone transmission was, apart from extraneous disturbing influences, dependent upon the two factors resistance and capacity. For some years after the introduction of telephony, transmission over long distances was, for reasons mentioned elsewhere, conspicious by its absence in this country, and, consequently, as the class of open line wire which the mechanical line constants demanded, gave satisfactory results for the comparatively short distances over which it was employed, the electrical line constants did not come under very close observation.

With the introduction of wires continuously insulated throughout their length and assembled closely together in the form of cable, however, difficulties were immediately introduced which were absent in bare overhead conductors; it soon came to be appreciated that the property of inductive capacity, possessed to a marked degree by such substances as were generally used as insulation, gutta percha, perhaps the commonest, exercised a very harmful effect in a telephone circuit.

It was not until the introduction of the dry core cable in 1891, to which more detailed reference is made in Chapter XII, that any notable advance was made in the design of cable conductors. The use of paper and air insulation applied in the manner peculiar to this class of cable had the important and beneficial effect of reducing the capacity by about one-half with a fourfold improvement in transmission efficiency. Early modifications made in line plant practice were introduced largely with a view to effect improvement in the stability and diminution in cost of overhead

lines, and an increase in the number of wires which could be accommodated underground in a given space, and therefore were more of a mechanical nature than electrical. Earth return circuits of overhead iron wire of various classes constituted generally the earliest practice, and no material improvement was effected until the invention of hard drawing gave to copper wire the requisite tensile strength for overhead line work, in addition to the superior conductivity it already possessed.

Although the introduction of metallic circuits to supplant the earth return resulted in an improvement in transmission, it was more in the nature of the elimination of overhearing, and in subduing inductive disturbance than in a direct transmission gain, and therefore needs but passing reference at this juncture.

At the present time, when nothing but metallic circuits for telephones are accepted as efficient, it is interesting to note that at one time in the early history of the telegraph, *i.e.*, about 1840, one may read of a discovery made by Carl Augustus von Steinheil that the earth could be used in place of a return wire. The employment of earth circuits subsequently became universal practice for telegraphs, and this practice was followed generally for telephones upon their introduction, and continued to be employed for many years. Incidentally, it was due to Steinheil that the superiority of copper to iron wire for telegraph purposes became generally recognised. Alexander Graham Bell experimented with both earth return and metallic loop circuits, and on November 20th, 1877, he took out a patent (Specification No. 4341) for the employment of a return wire in conjunction with the ordinary line wire provided for in his previous Specification No. 4765 of 1876, instead of relying upon the earth to furnish means to complete the circuit.

Prior to the year 1899, telephone engineers had very little conception indeed of the phenomena which accompanied the electrical transmission of speech along a telephone line. Previous knowledge of telephonic transmission amounted to very little more than was contained in the so-called K.R. law, a theory enunciated by Sir William Preece, but originally expounded in 1854, in relation to telegraphic transmission, by the late Lord Kelvin. This was to the effect that the limiting distance of telephonic speech was governed by the electrostatic capacity and the ohmic resistance of the circuit, and that speech was only possible

when the product of these two factors did not exceed a certain value. This value was given as :

For bare overhead conductors of copper . .	10,000
For bare overhead conductors of iron . .	5,000
For underground conductors	8,000

We now know that the K.R. law did not include all the factors which must be taken into consideration, and it was pointed out as long ago as 1887 by Oliver Heaviside that the theory had no true scientific significance.

The fundamentals of a law which showed the mathematical relationship between the electrical constants of a telephone circuit, and which adequately accounted for the phenomena of telephonic transmission, were first expounded and published by Oliver Heaviside in 1887. The same subject is also dealt with in the " Collected Papers " of the same author and in his well-known book on " Electro-magnetic Theory."

Heaviside's contribution to the art substantially was, to show mathematically that by balancing the product of resistance and capacity per mile against that of leakance and inductance, the form of a complex speech wave would travel without distortion; in other words, that by the addition of inductance to a line possessing harmful capacity, distortion might be annulled and speaking generally improved.

At the time of publication, the results of Heaviside's labours did not command the attention or the respect they merited, probably because they were unaccompanied by details of practical measures which should be taken to render them effective in actual practice.

Following Heaviside's publication, however, Professor S. P. Thompson made suggestions, in 1891 and 1893, for improvements in telephone cables, first, by the application of inductive shunts, and, secondly, by the interposition at intervals of transformers, in order to annul the distortive effect of capacity. The first of these proposals, described in British Patent Specification No. 22304 of December 21st, 1891, provided for the introduction of compensators into cables for signalling telegraphically or telephonically, for the purpose of breaking up the static capacity of the cable. The compensators were to be of the form of mutual, or self-induction, coils, of various arrangement and types, placed in the

cable so as to divide it into sections. The simplest form was that in which a coil of high resistance and self-inductance was placed in shunt across the two wires of the circuit. Specification No. 13064 of July 4th, 1893, dealt with further developments of the former patent, and provision was made for sectional and continuous loading, by wrapping the conductor with iron or other wire.

It was not, however, until 1899 that any practical issue from the mathematical expressions of Heaviside transpired, when the whole subject was freshly illuminated and a new aspect presented by Dr. Michael Idvorsky Pupin, Professor of Electro-Mechanics at Columbia University, New York, who, on March 22nd, 1899, read a paper before the American Institute of Electrical Engineers on the " Propagation of Long Electrical Waves."

Professor Pupin patented his invention in America in December 1899 and claimed " an improvement in the construction and installation of conductors for the transmission of electrical energy by means of electrical waves whereby, by decreasing the current necessary to transmit the amount of energy required, the attenuation of such waves is reduced and therefore the efficiency of transmission is increased." Broadly speaking, what Pupin really did was to indicate how Heaviside's mathematical theory, advanced twelve years previously, could be practically applied. He showed that a conductor of uniform inductance could be satisfactorily imitated, by one in which inductance was distributed along its length at certain regular intervals.

The final result of Pupin's efforts was the introduction of a practical method of augmenting the inherent inductance of a telephone circuit, by the interposition at intervals in it of what are now known as " loading coils."

Dr. Pupin was of German ancestry, but was born in Austria-Hungary in 1858. He went to America in 1874 and studied at Cambridge and Berlin. He began in 1895 the series of experiments which culminated in the invention of the Pupin loading coil.

The advances made in recent years in the subject of telephonic transmission had their origin therefore in the published works of Oliver Heaviside, a fact sometimes lost sight of. It is fitting that tribute should be paid to the genius of Oliver Heaviside, who was the first to provide telephone engineers with an adequate theory of telephonic transmission, although it lay practically disregarded

for as long as twelve years. Heaviside had the ultimate satisfaction, however, of seeing the fructification of his ideas, not perhaps in the manner he had imagined, but nevertheless in such a way as to bestow lasting and important benefits upon the telephone service and profession.

It is interesting to note that Oliver Heaviside is elder brother to the late A. W. Heaviside, at one time superintending engineer for the Northern District of the Post Office Engineering Department, who displayed great interest in the telephone upon its inception, and exercised much zeal in its introduction and early advancement in the North of England.

An entirely new field for investigation was thus opened up for the physicist and telephone engineer. The various telephone manufacturers and administrations were naturally most concerned with the possibilities presented by Pupin's discoveries, and were not slow to move in pursuing the subject. Pupin's investigations were immediately followed up assiduously by numerous physicists and telephone engineers both in America, and in this and other countries, acting either on their own initiative or on behalf of the telephone administration with which they were connected.

Those whose names have been most intimately associated with the advances made in the new science of telephone transmission since the publication of Pupin's work are mentioned below.

W. Duddell, London.
B. S. Cohen, of the National Telephone Co., Ltd., and later of the British Post Office Engineering Department.
J. G. Hill, of the British Post Office Engineering Department.
Professor J. A. Fleming, M.A., D.Sc., of the London University.
G. A. Campbell, of America.
Dr. A. E. Kennelly, of Harvard University.
Dr. Hammond V. Hayes, of the American Telegraph and Telephone Company.
J. J. Carty, Chief Engineer, American Telephone and Telegraph Company.
Professor Fessenden, of America.
Professor Breisig, of the German Telegraph Administration.

Pupin's original patent in Great Britain was described in British Patent Specification No. 12733 of December 14th, 1900.

Two arrangements of circuits were described; the first provided for the insertion at frequent intervals of inductive resistances in each side of the line, which was also bridged by a number of condensers. In the second arrangement, inductive resistances only were used. The form in which the inductance was to be employed was also given. It consisted of an iron core, in the form of a finely laminated open ring or cylinder, on which the wire, ultimately to form part of the line circuit, was wound.

British Patent Specification No. 16529, also in the name of M. I. Pupin, and dated December 14th, 1902, provided for improvements in the electric conductors described in the previously mentioned specification (No. 12733). It provided for the use of "twin coils," the two coils being wound on the same core so as to increase the inductance of each by the mutual inductance between them. A saving of space and material was thus effected. The coil was constructed in the form of a ring to diminish, as far as possible, the external magnetic field. Formulæ were given for calculating the dimensions of a coil to produce a given inductance, and for calculating the equivalent resistance of the coil, due to eddy current losses at a given frequency of magnetising current. Methods of winding the twin coils were described and illustrated.

The application of the Pupin principle of loading to phantom working is contained within Patent Specification No. 3423, in the name of T. Shaw, dated July 20th, 1911. This specification described an arrangement of loading coil windings which permitted of a third, or phantom circuit, being superimposed upon two loaded physical circuits.

In the British Patent Specification No. 3422 of July 21st, 1911, Messrs. G. A. Campbell and T. Shaw describe and illustrate, diagrammatically, how a phantom circuit derived from two loaded physical circuits, as arranged for in Specification No. 3423, might itself be loaded.

Due to the absence of adequate means for quantitative measurement, mathematical treatment of the subject of telephonic transmission was considerably in advance of actual experiment and attention was accordingly given to this most important branch of the subject.

Precise measurement was essential to progress. It was necessary in order to confirm mathematical investigation, to serve as a check or test of construction, and to furnish the engineer with

data for use in connection with the design of new plant. Practical methods for the determination and measurement of frequency, distortion, attenuation, current and energy of telephone waves, and impedances of lines and apparatus were needed. Measurement of the minute alternating currents of varying frequency used in telephonic speech, and of the constants of the telephone circuit in association with such currents, presented no little difficulty, however. It is not practicable to describe in detail the work done in this direction. The publications dealing with transmission measurements are of comparatively recent date, and should be referred to for detailed information. Brief reference should, however, be made to the early developments consummating Pupin's work which permitted of satisfactory measurements being made.

Mr. Duddell's oscillograph furnished means whereby telephone speech waves might be examined. By its means oscillograms of speech waves could be recorded, the differences between vowel and consonant sounds observed, and comparison of different voices could be made. The forms of the wave as transmitted, and as received, could be readily compared, and the effects of attenuation and distortion studied, as also the relationship between the transmitted and received currents.

Another instrument of great value produced by the same inventor and described by him in a paper read before the Physical Society in 1904, was the Duddell Thermo Galvanometer, an instrument of extreme sensitivity, very nearly approaching the telephone receiver in this respect. This instrument which, as its name implies, was a thermoelectric ammeter, provided means for accurately measuring the minute alternating currents, of frequency varying from roughly 100 to 4000 or 5000, utilised in telephony.

A further instrument for the measurement of small alternating or rapidly fluctuating currents is the Barretter or Bolometer. Bolometers or barretters have been used by Messrs. Langley, Tissot, Fessenden, Kennelly, Béla Gàti and Cohen. The instrument designed by Mr. B. S. Cohen and made by Mr. W. Paul, London, deserves special mention. It is described in Professor Fleming's work on "The Propagation of Electric Currents in Telephone and Telegraph Conductors," and also in an article by Mr. Cohen, in the *National Telephone Journal*, Vol. II, page

245. Prior to the introduction of the Duddell oscillograph and the barretter, no means existed for recording and measuring the minute currents used in the telephonic transmission of speech. By the use of the barretter, transmission tests of much greater accuracy could be made than by the previously adopted method of comparing sounds by ear, and in much less time. The barretter was also applied to tests of apparatus, as well as of lines, and proved valuable in the comparison of telephone transmitters, receivers, etc., with a standard instrument.

For measurements of small alternating voltages, the Drysdale-Tinsley alternate current potentiometer was produced in 1913. This instrument is also described in Professor Fleming's work mentioned above.

In the summer of 1904, the attenuation constant values for all types of line in common use in this country were calculated, to be afterwards experimentally verified in the research laboratory of the National Telephone Company. From the results obtained, a table of equivalents was compiled, one mile of 20 lb. low capacity cable being regarded as unity and used as a basis for comparison. These were the first authentic figures to be compiled in this country for relative transmission values of telephone lines of different types.

That branch of the art of telephony which deals with the question of transmission, has now assumed such importance and magnitude that it may be considered almost as a separate science and it is not possible to follow the matter further in these pages.

The more important events and contributions, which have led up to the modern conception and knowledge of the subject and present day practice in this country, have been briefly described. For fuller and later information, reference should be made to the modern publications on the subject, amongst which Mr. J. G. Hill's "Telephonic Transmission, Theoretical and Applied," should be specially mentioned as a complete and comprehensive treatise of the subject.

The Practical Application of the Pupin Loading Coil and Transmission Principles

No time was lost in adapting Professor Pupin's invention to the requirements of practical commercial telephony in this country.

In America, Professor Pupin's patent became vested in the

American Telephone and Telegraph Company. In England, Messrs. Siemens acquired the patent rights initially, but they were subsequently transferred to the Western Electric Company, who thereupon undertook the manufacture of the loading coil and developed it to its present state of perfection.

After careful experiment and investigation had been carried out, the Pupin coil was applied commercially to circuits already in actual use in the Metropolitan area, between the Gerrard and Croydon exchanges of the National Telephone Company. No record of the improvement effected in this case is available, but it is understood that the calculated improvement anticipated was actually realised.

Further loading was completed in the Metropolitan area in June 1908, when trunk junctions to the company's exchanges at Sydenham, Bromley and Kingston were subjected to similar treatment and the following results were obtained.

	Equated length.	
	Before loading.	Loaded.
Sydenham	7·4	2·9
Bromley	11·5	4·4
Kingston	13·0	4·8

A scheme of loading which may perhaps not inaccurately be termed the first comprehensive scheme of loading embarked upon in this country was one for the application of loading coils to 50 junction lines radiating from the Birmingham Trunk and Central exchanges to various sub-exchanges situated in the surrounding territory. The results obtained on completion of the work, carried out under the direction of the author in 1908, were in every way satisfactory, and demonstrated in a practical manner the efficacy of loading even comparatively short lines. Particulars of the lines loaded and the results obtained as determined by tests carried out personally by Mr. B. S. Cohen, who designed the loading system, and Mr. R. Shepherd are given in tabular form in Table 17. The author is indebted to Mr. Cohen for the figures he is enabled to present.

The British Post office commenced to experiment with loading

coils early in the year 1901, when results obtained with 25w. induction coils were of such promise that a number of coils were specially constructed and inserted experimentally in the London-Birmingham underground cable. Certain improvements in telephonic speech were observed, but no quantitative results appear to have been recorded.

The first trunk circuit to be loaded for practical purposes appears to have been a trunk line between Liverpool and Warrington, in May 1903. Air core coils were used and an improvement factor of 2·75 was obtained. The results being favourable, further loading of circuits for commercial purposes was carried out, the principal examples of early loading undertaken by the British Post Office being scheduled in Table 18.

In April 1908 lengthy experiments were conducted by engineers of the Post Office on the Manchester-Liverpool cable line with a view to the determination of the relative merits of the Post Office air core coil and the Western Electric Company's toroidal iron core coils. The conclusions reached were generally to the effect that air core coils were less efficient, more liable to deterioration, and subject to external induction than the iron core coil. The following figures illustrate the relative transmission efficiency of the two types of coil as then determined.

	Improvement factor.
Post Office air core coils	3 : 1
Western Electric Co.'s iron core coils . .	3·8 : 1

The use of air core coils was therefore abandoned in favour of iron core coils.

The advantages to be derived from loading in this country are to a certain extent more limited than in countries and continents with wider boundaries. Its application to open wires is less effective than when used in conjunction with cable lines, owing to the larger inherent inductance of the former. Nevertheless, the adoption of loading on open wire lines of considerable length in America has been effective and commercially successful. It has been considered that with the less favourable climate in this country the leakance factor, with its detrimental effect, plays a more important part, and the loading of open wire conductors has not, therefore, progressed very much beyond the experimental stage.

The uses of loading in the United Kingdom have been, and no doubt will continue to be, more in the direction of (1) reducing the cost of copper in underground lines of given length and (2) enabling use to be made of underground lines for longer distances than heretofore has been permissible, and so rendering the longer distance services more immune from the temporary, but nevertheless serious, dislocation to which they have been subject on numerous occasions by serious storms and other climatic disturbances.

The gain in knowledge of what may be termed the new science of telephonic transmission from the Heaviside-Pupin investigations eventually resulted, not only in the practical application to telephone cables of " loading," but also to extensive and important modifications to the standards of construction previously in vogue for telephone plant of various descriptions, and in particular to cable plant.

In a telephone system, the preponderance of telephone conversations are for short distances only; they are usually confined to the comparatively small area occupied by the commercial, industrial and residential community, which generally comprises a centre of activity. Longer distance conversations, wherein junction or trunk lines are employed, are usually but a small percentage of the total conversations.

In larger areas containing several exchanges connected by junction lines, the number of calls, other than those operated at one exchange, are greater in proportion, but nevertheless the true long distance calls are still but a small proportion of the total.

Previous to the scientific study of transmission which transpired from Heaviside and Pupin's investigations, underground conductors used for local conversations were for the most part composed of copper wires weighing 20 lbs. per mile, this being generally recognised as standard practice. Conductors in underground cables utilised for junction and in some cases trunk line purposes were commonly of the same gauge, in order to avoid necessity for composite cables which were not favoured. In the Post Office underground system in London, opened in 1902, 20 lb. circuits were at first used for subscribers' circuits, and 40 lb. for junctions.

Study of transmission revealed that, for the short distance calls, which, as previously pointed out, preponderated, the gauge

of the conductors used was considerably more than was necessary to give efficient speech, and therefore that, within certain limits, a reduction in gauge was permissible in so far as local service was concerned. For certain longer distances, such a reduction would also afford speech which might be considered satisfactory, while in others this would not be the case. No standard of speech transmission had been adopted, and therefore the quality of speech between subscribers situated in different parts of the country, where trunk facilities existed, varied very considerably. Here was matter for investigation and rectification.

One of the first requirements was a unit by which the quality of speech or "audibility" might be measured or with which it might be compared. The standard unit, adopted in this country in 1904, was the same as that adopted previously in the United States by the American Telephone and Telegraph Company's engineers, viz., the mile of standard cable, standard cable being defined as "a telephone dry core cable, the wires of which have a loop resistance of 88 ohms per mile and an average mutual electrostatic capacity of 0·054 microfarad per mile between wire and wire of each pair, and an average insulation of not less than 200 megohms per mile between wire and wire of each pair, all measurements being made at 60° Fahrenheit."

It was necessary also to have standard instruments, which were defined as "common battery instruments fed by a battery of 22 volts through a circuit which, except so far as it consists of exchange apparatus and subscribers' instruments, shall have a resistance of 300 ohms."

It has been computed that from 60 to 70 per cent. of the capital value of a telephone system lies in the line plant, mostly therefore in copper, and by far the greater proportion of copper expended on a telephone system is absorbed by the local line plant, *i.e.*, subscribers' direct exchange lines; hence if even a small reduction could be made in the gauge of the conductor used a very considerable reduction in the capital cost of providing subscribers' lines would follow. To counterbalance the loss in transmission when a subscriber's circuit was used in association with junction or trunk lines, it was feasible that the transmission efficiency of the latter could, as opportunity arose and where necessary, be improved by increasing the size of the trunk conductor. The additional cost of copper thus utilised in improving the trunk lines being

practically negligible when compared with the saving effected in local line plant.

The trunk line system was wholly controlled by the Post Office and the local and junction service and the plant associated therewith were, with the exception of the few Municipal systems still operative, the London Post Office system and the comparatively small Post Office local systems in the Provinces, in the hands of the National Telephone Co., Ltd.

Obviously the trunk line system and the local line system could not be considered independently. Co-operation was therefore necessary if the most economical and efficient transmission system was to be evolved.

The agreement entered into between the Postmaster-General and the National Telephone Co., Ltd., dated February 14th, 1905, which provided for purchase by the Postmaster-General of the National Telephone Company's plant and assets included, as its Third Schedule, a "Specification and Rules as to Plant," to which, with certain provisions, existing and newly-constructed plant should conform. An important part of this schedule imposed certain standards of speech transmission, in terms of standard cable, or "Test Cable," as it was termed in the specification; it had the effect of regulating construction, not by specifying the type of plant to be used, but rather the result in transmission units (miles of test cable) which was to be attained. This section of the specification formed, therefore, an early instance of the practical application of the standards of transmission.

The standards of transmission contained in the "Specification and Rules as to Plant" referred to, were determined by transmission tests conducted in the National Telephone Company's laboratory jointly by officers of the company and of the Post Office.

The transmission limits imposed for local conversations varied, according to radial mileage, from ten to thirty-five miles of test cable, and for trunk conversations was either eight or five miles of test cable, according as to whether the sum of the radial distances between the separate operating points exceeded nine miles or not.

Numerous views have been expressed as to the wisdom of applying different standards of transmission, varying according to the distance apart of two telephone correspondents. It has

been argued convincingly that there is no reason why two subscribers situated at extremities of the country, should be given speech inferior to that between two subscribers situated in the same town or street. On the other hand, that so long as commercial speech is afforded between far distant subscribers they have no cause for complaint if greatly improved speech is available between neighbouring subscribers without prejudice to the question of economics. After careful investigation, it was generally accepted that speech would be commercially acceptable so long as it did not fall below the extreme limit represented by about 46 miles of standard cable. Under the worst conditions, two subscribers in close juxtaposition may enjoy a quality of speech of the order of one or two miles of standard cable, or even less, but when one of these same subscribers desires to speak for long distances the quality of speech is subject to considerable diminution.

There is a limit of transmission beyond which undoubtedly it is undesirable to go, but the accident which places two subscribers in close proximity one to the other, cannot, for practical reasons, be utilised to secure further economies. There is, for mechanical reasons, a practical limit to which the gauge of conductors contained in underground cables may be reduced; similarly, while transmission would permit a considerable reduction in copper, or more correctly bronze, for subscribers' open wire circuits, mechanical considerations forbid. It follows therefore that the speech between two closely adjacent subscribers must needs be better than actual requirements demand, and that for long distances a standard must be struck, which will adequately satisfy the requirements of audible speech, with a margin for contingencies, which is compatible with cost.

The arbitrary standards in use by telephone administrations previous to the new conception of telephonic transmision were thus swept away, a series of standards founded on a sound basis was adopted, and telephone circuits and systems of line plant associated with exchanges began to be designed on more scientific lines than formerly.

The first effect upon the line plant of the application of the principles of transmission, apart from the adoption of practical commercial loading, was the introduction of the fine wire cable. Circuits of copper wire, weighing 20 lb. per mile, had hitherto

been universally used for subscribers' circuits in underground cables and, immediately the use of a lighter gauge wire was found to be practicable, *i.e.*, in 1905, 10 lb. cable was introduced, thus approximately doubling at once the number of conductors accommodated in a given space, and halving the cost of copper, a most notable economic advance in line plant practice. For comparatively short distances, *i.e.*, for lines terminating within a radius of not more than about $1\frac{1}{2}$ miles from the exchange, the use of 10 lb. cable was generally feasible throughout the whole length of the underground portion of the circuits. For greater distances, broadly considered, the use of 20 lb. cable was necessary.

Combinations of 10 lb. and 20 lb. conductors in series, so long as the transmission limits were not exceeded, were also permissible. The design or lay-out of an underground cable system now became a much more involved matter than it had been previously. It became necessary, not only to arrange for distribution of pairs of wires to accord with the predetermined figures of the development study, but also to secure the minimum expenditure of copper which would conform to the transmission limits; in other words, not only was it essential to determine, on an economic basis, the number and distribution of pairs to be provided, but also the minimum standard gauge of conductor which would fulfil the transmission requirements.

For short distances, transmission was satisfied by the use of 10 lb. conductors, for longer distances a combination of 10 lb. and 20 lb. conductors would suffice; for longer distances still, 20 lb. cable throughout was necessary and for certain exceptional cases of long distance subscribers' circuits, even a heavier gauge might be necessary.

The design and distribution of circuits in cables required to serve groups of subscribers' circuits of widely varying lengths presented special difficulty. In order to avoid the complexities introduced by, and objections attaching to the use of composite cables for subscribers' distribution, always subject to fluctuations, the paralleling or bunching of two or more circuits of small gauge was feasible to a certain extent.

In the consideration of schemes for new cable plant, for places where underground plant had already been laid, the utilisation to best advantage of the existing plant, in conjunction with the

new, was a problem bringing with it further complications and difficulties, which none but those who have had intimate experience with such problems are able fully to appreciate.

The effect on transmission of signalling and other apparatus, necessarily included in the speaking circuit, had also to be taken into account, as also the possibilities of the application of loading.

All these considerations rendered the design and lay-out of an underground cable system a matter of no small difficulty and presented to the telephone engineer a fresh field for investigation and study.

In the study of line plant requirements, it soon became apparent that, in the immediate vicinity of an exchange, the transmission value of 10 lb. cable was actually in excess of requirements, and it became a question for investigation whether or not wires of even lighter gauge than 10 lb. could not be used with impunity. The question became one not as to whether a lighter gauge would or would not be practicable from a transmission point of view only—for it was clear that although each case as it arose would require consideration on its merits, yet there was a field for the use of conductors of less gauge than 10 lb.—but rather as to whether wire of less than 10 lb. in weight would fulfil the mechanical requirements of the cable manufacturer and of the installer. There was a fear that wires of smaller gauge than 10 lbs. per mile would present serious difficulties in cable laying and jointing, that the thin wire would not possess the requisite tenacity to render jointing by the usual methods a safe and reliable practice.

However, cables containing conductors having a weight of no more than $6\frac{1}{2}$ lb. per mile were ultimately manufactured and introduced in 1909, with entirely satisfactory results, and the use of $6\frac{1}{2}$ lb. cable became customary where transmission permitted. The introduction of an additional gauge of wire for telephone exchange line systems brought with it still further complications in the design of underground plant, and the preparation of schemes for the installation of cables on a large scale presented problems which were entirely absent in the days when 20 lb. conductors only were universally used for all subscribers' underground circuits.

At the period in which the introduction of the fine wire cable came about, the transmission limits stipulated in the specification and Rules as to Plant, included in the agreement entered into

between the Postmaster-General and the National Telephone Company on February 14th, 1905, were in force. The problem presented to the company's engineers in all cases was the economic one of arranging local underground systems, including subscribers' lines and junction lines, for present and future requirements, in such a manner, as to secure the use of the minimum weight of copper which would comply with the stipulated limits of speech, expressed in terms of standard cable.

CHAPTER XVIII

LONG DISTANCE COMMUNICATION BY TELEPHONE, 1879–1922

COMMUNICATION by telephone over increasingly long distances has been the dream of telephone engineers ever since the first practical conversation over a telephone line took place.

The speed at which electricity travels being equal to that of light, viz., 186,000 miles per second, the telephone may be said to annihilate time in so far as the transmission of intelligence is concerned, and the question of time or speed of transmission did not, therefore, enter into consideration, in regard to long distance conversations, any more than it did into the shorter.

By reason of the comparatively narrower confines of this country, the field presented to the engineer for increasing usefully the practical limiting distance over which speech might be transmitted was, and still is, much more restricted than in America, and for this reason, as well as for several others of a non-technical character mentioned later, the progress made in the United Kingdom was quickly eclipsed by that of America.

One of the first long distance experiments made in this country was that referred to in Chapter II, when communication was accomplished over a single wire between London and Norwich, a distance of 115 miles, by means of the Edison carbon transmitter and Bell receiver. Although this conversation is recorded as having been conducted satisfactorily, it is extremely unlikely that the quality of transmission was such as would now be regarded as acceptable.

Inter-town telephonic communication at first developed much more rapidly in the provinces than in the neighbourhood of London. When the circumstances are taken fully into account, it is, perhaps, not surprising that this should have been the case. In the Midland Counties, and in Lancashire, Yorkshire, Durham, Northumberland, and the territory contiguous to the Clyde and the Forth in Scotland, there are groups of towns not very far

distant one from another in which the chief industries were, and still are, closely allied, and where telephone communication was bound sooner or later to become a boon to the communities there established. London, on the other hand, remains to this day more or less isolated by long distances from other large centres of activity, and therefore the possibilities of communication by telephone with other towns were less in the case of London than for the grouped towns of the provinces. Consequently, the nucleus of the present-day long distance telephone system of the United Kingdom was laid first in the more thickly populated parts of the Provinces.

Prior to the monopoly of the telephone business being vested with the Government, as a result of the judgment delivered in November 1880 in the case of the Attorney-General *versus* the Edison Telephone Company and the Telephone Co., Ltd., the various companies and firms who had established telephone exchange systems were not prevented from providing inter-town service, and as a consequence some few lines joining certain towns one with another had been erected and brought into use. These lines were few in number, however, and when, after the litigation referred to, licences to carry on telephone business were issued by the Postmaster-General, stipulations were included restricting operations to an area defined by a radius of three, four, or five miles, as the case might be, from a prescribed centre, and the licensees were prohibited from furnishing means of communication between exchanges situated in different towns. This policy was adopted as a protective measure for the telegraph service, fears being entertained at that time that the telephone business might affect prejudicially the revenue derived from the telegraphs if permitted to provide for long distances without discrimination. Local telephone service was not so likely to compete seriously with the telegraph, but for long distance communication the telegraph at that time stood alone, and the view of the authorities was that it must be adequately preserved. Consequently, the long distance or, as it has become more generally known, the trunk line service did not at first develop at a rate commensurate with the development of the local service.

Another reason why the trunk service did not develop quickly probably was that the telegraph network built up by the private telegraph companies, and subsequently developed to a state of

high efficiency by the Post Office, provided fairly fully for the public needs in inter-town communication, and it was not until local telephone systems were serving comparatively large groups of subscribers that the demand for inter-town service became appreciable.

As, however, the local service became established and popularised, and the number of subscribers to the various exchanges increased, the need for intercommunication between distant towns became apparent, and endeavours were, therefore, made to arrive at some arrangement by which the required trunk lines might be provided. Eventually the Government relaxed its attitude in regard to inter-town service and it was agreed that trunk circuits required should be constructed and maintained by the Post Office, and that the telephone companies should rent such circuits from the Post Office under certain conditions, one of which was that an annual rental of £10 per mile should be paid by the companies in respect of all such rented lines.

One of the earliest, if not the first, successful trunk line to be brought into use for commercial purposes was erected in 1880 between Leeds and Bradford. The use of this line was, however, discontinued until the arrangements between the telephone companies and the Postmaster-General alluded to, were completed. The service between Leeds and Bradford was ultimately re-established in 1882.

The telephone companies did not regard as satisfactory the arrangements concluded with the Government for the provision of trunk lines, and the consequence was that up to 1884, when a change of policy came about, comparatively few circuits existed between town and town. The records available regarding the number of inter-town lines worked in the early days of the telephone are scanty and also misleading, inasmuch as all lines connecting exchanges, whether in the same or different towns, were commonly known as trunk lines, and it is, therefore, impracticable to distinguish between true inter-town, or trunk lines, and junction lines, as they came to be termed later on.

London itself was entirely without telephone communication with a provincial town until December 17th, 1884, when a trunk circuit between London and Brighton, was opened for service. The line was erected by the Post Office, for the United Telephone Company and was a metallic circuit of copper wire.

A few comparatively short trunk lines had by this date been opened up in the provinces, notably between certain towns in the neighbourhood of Glasgow and Edinburgh, in the Midlands including Leeds, Bradford, Huddersfield and Sheffield, between Birmingham and certain neighbouring towns, and between Sunderland and Newcastle, and the towns in the immediate vicinity thereof.

Early in 1883 it was announced that a company, to be termed the Long Distance Telephone Company, was about to be formed in this country, for the purpose of working the patents of an American named Hopkins. According to the prospectus issued by the promoters of the company, it was intended to erect trunk wires between London and most of the important towns in the kingdom, and figures were quoted representative of the cost of erection of trunk circuits between London and Liverpool and other large towns. The promoters evidently reckoned without the Postmaster-General and his powers, and also without the United Telephone Company's patents, for in May 1883 the United Company brought an action against the Long Distance Company for infringement of the Bell and Edison patents, and sought an injunction to restrain the sale or use of the Hopkins instrument, pending trial of the action. It would appear that a compromise was arranged between the two companies, wherein the Long Distance Company agreed to submit to an interim injunction, without prejudice to the result of the action, should it be tried, but whatever happened the Long Distance Company's scheme did not fructify.

It would appear that expansion of the local service was affected by lack of facilities for providing unlimited trunk services, and in those few places where trunk lines were provided the development of the telephone was more marked than in those places where such facilities were not afforded. In the interests of the telephone service it was desirable, therefore, that the conditions which were not conducive to the development of the trunk service should be removed, and eventually an entirely new policy was adopted and many of the difficulties under which the several companies were working were swept away. The circumstances under which this change of policy by the Government came about, resulting in the substitution of new for the old indentures held by the several companies, are related in Chapter XXI.

On November 29th, 1884, new licences were granted to the United Telephone Co., Ltd., the Lancashire and Cheshire Telephonic Exchange Co., Ltd., the Telephone Company of Ireland, Ltd., and the Northern District Telephone Co., Ltd., in place of the old ones which were surrendered, and the territorial restrictions limiting the operations of the several companies to a definite radius, were removed. The principal provisions of the new indentures were as follows.

1. Licences were for a term of 31 years from January 1st, 1881, as before.
2. Spoken messages only were to be permitted, written messages being vetoed and the making of any copy, transcript, memorandum or note of any message or communication was prohibited, the company being responsible for taking proper precautions to secure the observance of this condition. It was provided, however, that the sender or receiver might make a note or memorandum of the purport of any message so long as it was for the purpose of his business or private affairs.
3. No messages were to be collected or delivered.
4. In case of breach of these conditions on the part of a subscriber the company was bound to determine the contract or agreement which had been made with him and to advise the Postmaster-General of the circumstances.
5. The company was not to use any unlicensed telegraphs.
6. The company was to pay quarterly to the Postmaster-General ten per cent. of the gross receipts as royalty.
7. Suitable business accounts were to be kept and were to be open to inspection by the Postmaster-General at all reasonable times.
8. Quarterly accounts were to be furnished to the Postmaster-General in such form as he might require.
9. The Postmaster-General was empowered to inspect the company's works at all reasonable times.
10. The licence was not to be assigned or underlet.
11. The telephone company's works were not to interfere with the Postmaster-General's telegraphs.

12. The Postmaster-General might at any time, by six months' previous notice in writing terminating on the 31st day of December, 1890, 1897 or 1904, signify his intention to purchase the business of the company and the company was bound to sell.

Immediately the new indentures were entered into, the telephone companies set to work vigorously in the construction of trunk lines and in the opening up of intertown communication, and such was the activity that in the space of five years a large number of towns in the provinces were provided with facilities for intercommunication.

The trunk line system developed most rapidly in the territories worked by the Lancashire and Cheshire, the National and the Northern District companies. These companies adopted a particularly enterprising policy in the construction of trunk lines, but they were assisted to some appreciable extent by the fact that their spheres of operation, centred respectively in Liverpool, Glasgow and Sunderland, embraced many towns of industrial importance situated at moderate distances apart. Attention was first given by the several companies to the development of the trunk service within the confines of their own particular territory.

One of the first trunk lines to be constructed under the new arrangements, was opened by the Lancashire and Cheshire Company between Liverpool and Manchester. It was a single circuit about forty miles in length, built along the Cheshire Lines Railway, the rails being used as return circuit. It was opened for service on January 1st, 1885.

The type of construction at first adopted differed according to the views of the responsible engineers. In most cases single earth circuit lines were first erected, No. 11 galvanised iron and No. 14 hard drawn copper wire being commonly used. The Lancashire and Cheshire Company employed single circuits for the most part composed of No. 16 B.W.G. hard drawn copper wire. In Glasgow and the territory in Scotland controlled by the National Telephone Company, metallic circuits of No. 14 B.W.G. hard drawn copper wire were principally used, but single lines were employed for the shorter distances.

The telephone trunk line between Edinburgh and Glasgow,

brought into practical operation early in 1884 by the National Telephone Company, was at the time the longest telephone line in the kingdom. In the early days of the trunk service Scotland appears to have been better served with trunk lines than any other locality, and the increased facilities afforded for long distance communication accelerated expansion of the local service.

In the Northern District also, the home of the metallic circuit as it may, not inappropriately, be termed, trunk communication was afforded by means of metallic circuits both by the Post Office and the Northern District Company, and this district also was well served by trunk lines by the date in question.

The establishment of trunk communication was usually signalised by special transmission of music to the favoured town over the newly-constructed trunk circuit, and by conversation between prominent residents of the towns concerned; in this way the feasibility of long distance transmission was demonstrated and the new facilities for communication were advertised.

In 1886 communication was established between Leeds and Manchester.

In 1887 a scheme was evolved for linking up, by means of trunk lines, the local telephone systems worked by the National, the Lancashire and Cheshire, and the Northern District companies, and during the following three years trunk line construction proceeded rapidly between towns situated in the territory worked by these administrations.

In the summer of 1885 trials were made by engineers of the Post Office with the object of determining the possibilities of long distance transmission. The experiments were conducted between Uxbridge and Liverpool, a distance of about 200 miles, and in the opinion of the experimenters the results of the tests indicated that it was possible to communicate between points situated twice that distance apart.

In 1886 Mr. W. H. Preece, F.R.S., gave an address before the Society of Telegraph Engineers and Electricians entitled "Long Distance Telephony," and on March 3rd, 1887, Mr. Preece read a paper before the Royal Society "On the Limiting Distance of Speech by Telephone."

As stated, the classes of wire variously employed by the telephone companies for trunk purposes throughout the country were No. 11 galvanised iron, and Nos. 16 and 14 hard drawn copper, and both

single and twisted metallic circuits were employed; where metallic circuits were provided, use was sometimes made of translators for superimposing purposes, but the results were not good. In 1885 such translators were generally dispensed with, and the two wires formerly constituting a metallic circuit were used as independent circuits, with earth return, and continued so in use up to 1888. In this year the use of No 14 B.W.G. copper wire became common, and metallic circuits of this composition were utilised for opening up service between Birmingham and Sheffield, Birmingham and Derby, Derby and Nottingham, and additional circuits of the same composition were erected between Birmingham and Wolverhampton. The results were satisfactory, and further metallic circuits of No. 12½ B.W.G. copper wire were provided from Sheffield to Bradford and Leeds, and from Sheffield to Huddersfield; further use of iron wire for conductors was abandoned.

Prior to 1890, the provincial towns were in a much superior position to the Metropolis in respect of trunk communication. In 1889 London was entirely without long distance communication with the single exception of the line to Brighton, already referred to, neglecting the short trunk lines which existed to Tilbury and Croydon, whereas in the Provinces communication was possible between most of the more important centres of industry. Records show that at this date communication existed between the provincial towns undermentioned :—

Birmingham, Liverpool, Manchester, Leeds, Sheffield, Nottingham, Bradford, Huddersfield and other contiguous towns.

Glasgow and Edinburgh and neighbouring towns.

Newcastle, Sunderland, Middlesbrough, Stockton, West Hartlepool, Darlington and other towns of lesser importance in proximity thereto.

In 1888 a project was mooted for opening up telephonic communication between London and the large towns in the Midlands, and for that purpose it was decided to proceed with the erection of a line between London and Birmingham, with the intention that, if successful, the service would be extended from Birmingham to other towns in the Midlands already connected to that city. Birmingham was at that time the central trunk switching station for the Midland towns, and was situated nearest of them all to London.

The design and construction of this trunk line was the most important work of the kind attempted up to that time in this country. The work involved was of some magnitude, and included the erection of a new pole line for the greater part of the total distance of approximately 130 miles. When completed, the new line would form the longest trunk line in the country.

Four pairs of 150 lb. wires were erected, two circuits for Birmingham, one for Manchester and one for Liverpool.

There was some speculation as to the success which was likely to attend the effort and the United Telephone Company was criticised in respect of the wisdom of employing the No. 12½ B.W.G. hard drawn copper conductors decided upon. Communication between the two fixed points forming the extremities of the proposed London-Birmingham trunk appeared to be assured, but doubts were expressed as to the feasibility of conversing between a London and a Birmingham subscriber, based on the facts that in London a large proportion of the line plant consisted of overhead iron wire, aerial cable conductors insulated with gutta percha, and underground conductors in the subways, and Metropolitan District Railway; also there were 21 exchanges in London, each of which would necessitate inclusion in the circuit of electro-magnets. In Birmingham the greater part of the subscribers' lines were underground gutta percha-insulated conductors, and there were several subsidiary exchanges, through which it was essential that conversations from London should be passed.

The construction of the line was subject to numerous obstructions and delays in the form of wayleave difficulties. Trouble was first encountered at Stourbridge in objections, made by private property owners, to the erection of the necessary poles, and a wide detour had to be made in the line in order to avoid the properties of objecting parties. The Hendon and Hampstead local authorities also made objection to the erection of poles through the territories over which they had jurisdiction, and placed serious obstacles in the way of the completion of the line. This latter difficulty was surmounted eventually by utilising the Finsbury Park and Edgware line of the Great Northern Railway for conveying the circuit into London. The objections raised appeared to be due to general opposition to the telephone, the possibility of damage being occasioned, and to an impression that the poles would be

detrimental to the amenities of the properties and neighbourhood. The question of the desirability of seeking Parliamentary powers in order to circumvent similar objections was much talked of at this time.

All the difficulties met with were, however, eventually surmounted, and trunk communication between London (Oxford Court) and Birmingham, was finally established on July 10th, 1890. Thus for the first time telephonic communication was opened up between the Metropolis and the Midland and Northern Counties.

In Chapter IX mention is made of the influence exerted by the difficulties experienced in the management of the increasing trunk traffic, towards the policy of amalgamation of the telephone companies which commenced in May 1889.

In 1889 the problem of establishing telephone communication between Great Britain and the continent of Europe arose; it was first mooted by the Minister of Posts and Telegraphs in Paris, who suggested the desirability of providing facilities for conducting telephone conversation between London and Paris. The matter was immediately taken up by the British Postal Authorities and in the same year Mr. W. H. Preece addressed a meeting of the British Association at Newcastle-on-Tyne on the subject. At that time long distance telephone communications were represented by the following :—

New York–Chicago.	900 miles	—
New York–Boston.	350 ,,	1884
Paris–Brussels.	190 ,,	1889
Paris–Lille.	158 ,,	1889
Paris–Havre.	135 ,,	1889
Paris–Marseilles.	600 ,,	1889

The distance between London and Paris comprised 74 miles London to Dover, 21 miles Dover to Calais, and 180 miles Calais to Paris.

Attempts to telephone from London to Paris by means of the available telegraph lines, failed. Mr. Preece eventually constructed an artificial line, which reproduced as nearly as was at that time possible the proposed London to Paris circuit. Speech was found quite practicable and the matter was, therefore, proceeded with.

The chief difficulty to be surmounted was the design of a submarine cable, suitable for telephone working, to be laid across

the English Channel. Several cables for telegraph purposes had already been laid between England and France, but the design of a telephone submarine cable was a problem presenting complexities which did not arise in the case of telegraph working.

The cable was designed by Mr. H. R. Kempe, manufactured by Messrs. Siemens Bros. and Company to the specification of the Post Office, and laid by Her Majesty's telegraph ship "Monarch." It contained two circuits of 160 lb. copper per nautical mile, each conductor being made up of seven strands of wire 35 mils in diameter. The electrical resistance was approximately 7·5 ohms per knot. The insulation was composed of three alternate layers of Chatterton's compound and gutta percha, to a weight of 300 lbs. per knot. The minimum insulation

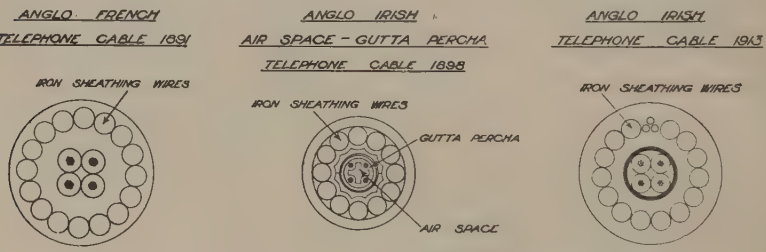

Fig. 162.—Early Types of Telephone Submarine Cable.

resistance specified was 500 megohms per knot, and the capacity 0·3045 microfarad per knot. A cross section of the cable is given in Fig. 162; its total length was 20·97 knots. The landing points of the cable were St. Margaret's Bay in Kent and Sangatte in France.

In so far as the land sections of the line were concerned, service was maintained, on the English side, by means of conductors weighing 800 lbs. per mile, and in France 600 lbs. per mile. The French land line included seven kilometres of Fortin-Hermann cable, laid underground, and consisting of conductors over which beads, treated with paraffin, were threaded, the whole being enveloped in a lead pipe.

Telephonic communication between Great Britain and the Continent was thus for the first time established with two circuits between London and Paris. The service was thrown open to the public on Wednesday, April 1st, 1891; the charge for three

minutes' conversation was 8*s*. The total cost of the two circuits was £23,704.

At the time the London-Paris line was under construction and shortly before the Channel cable was laid, *i.e.*, in September, 1890, Mr. W. H. Preece, F.R.S., delivered a paper before the British Association (Section G) at Leeds entitled "On the Form of Submarine Cables for Long Distance Telephony."

In May 1892 consideration was given by officers of the National Telephone Company to the more important features of trunk line construction; based on the experience gained, the following decisions were arrived at, and in order to secure uniformity of practice they were brought into force universally.

(1) Trunk and junction circuits to be composed of hard-drawn copper wire of not less weight than 100 lb. per mile.

(2) The weight of wire to be employed to be regulated according to distance as follows :—

Distance in miles.	Weight of copper wire in lbs. per mile.
100	100
150	150
200	200
250	200
300	250
350	350
400	400
450	500

In determining these weights, allowance was made for inclusion in the circuit of five miles of cable, or two repeaters (or translators), the latter to permit of satisfactory speech between single line subscribers' lines at each end of the trunk circuit. The weights quoted took into consideration only the requirements between specific points; where any line was likely to be extended beyond its normal extremities, the weight of wire suitable for the entire distance over which communication might be required, was to be selected.

(3) The length of span for overhead trunk lines was not to exceed 60 yards.

(4) The separating distance between wires was to be 12 inches, and the distance from the centre of the pole to the nearest insulator was not to be less than 9 inches.

(5) All trunk circuits were to be erected with a right hand twist, and the regulation of the first loops erected on any line was to be adjusted by dynamometer.

Although the trunk line system built up by the telephone companies created traffic of its own and fulfilled a function quite apart from the telegraphs, there is no doubt that to a certain extent it detracted from the telegraph traffic and consequently reduced the telegraph revenue, a perquisite of the State. The Government was apprehensive that if the telephone trunk line system continued to be developed by the telephone companies as vigorously as it then was, it would to some extent supersede the use of the telegraphs. Moreover, in the year 1892, it was manifest that, in certain quarters, there was a strong desire that opportunity should be afforded to institute telephone service in competition with the National Telephone Company. The National company, being in possession of the main lines of communication, were in an almost unassailable position in their ability to meet such competition by declining to permit subscribers connected to competitive systems the use of the trunk lines they owned and which had been laboriously built up by them and their predecessors.

The establishment of a dual system of trunk lines, although not impracticable, was highly undesirable, and as it was regarded as essential in the interests of the community, that new telephone administrations should have the right to offer their subscribers unrestricted trunk service, the Government came to the decision that the trunk line system should be owned by the State, and, as a consequence, the Telegraph Act of 1892 was passed. The circumstances which culminated in the passing of this Act are related in Chapter XXI. The Act made financial provision for the purchase of the main lines of telephonic communication, and for the development of the system by the Postmaster-General, by authorising the Treasury to issue out of the Consolidated Fund sums not exceeding one million pounds to be devoted to that purpose. Heads of arrangement for the sale of the trunk lines were entered into on August 11th, 1892.

It was intended originally that the price to be paid for the company's trunk line system was to be the cost price, plus ten per cent. to cover the administration costs, but it was found to

be impossible to assess the price on this basis, because the plant associated with the trunk service was inextricably mixed with the local line plant. It was therefore necessary to make an actual survey of the whole of the plant concerned. The valuation of the plant to be purchased was placed in the hands of Sir John Gavey and Mr. Dane Sinclair, representing respectively the Post Office and the National Telephone Company.

On March 25th, 1896, an "Agreement as to Trunk Lines" was entered into between the Postmaster-General and the National Telephone Company, and contained the following provisions :—

(*a*) Purchase of trunk lines erected to August 11th, 1892, at a cost of £440,949 10*s*. 7*d*.
(*b*) Trunk lines to be handed over on April 4th, 1896.
(*c*) The National Telephone Company's business was, in future, to be confined to Exchange areas.
(*d*) The powers of the Telegraph Act, 1892, were to be conferred upon the company.

A supplementary Agreement as to "Transfer of Trunk Lines and other Telegraphs," was entered into on March 26th, 1896. This covered the purchase of trunk lines erected from August 11th, 1892, to the date of the agreement, for the sum of £18,164 13*s*. 0*d*.

The total wire mileage transferred to the Postmaster-General by these two agreements was 28,998 miles 1523 yards and the total purchase price £459,114 3*s*. 7*d*.

A Telegraph Act, dated August 1896, authorised a further £300,000 to the sum of money authorised by the Act of 1892, and for the same purpose.

While the arrangements for the transfer of the privately owned trunk line system to the State were in progress, the Post Office had not been idle. A scheme for a backbone system of trunk lines connecting the principal towns of England, Scotland and Ireland, for which financial provision was included in the Act of 1892, had been devised and the work put in hand. The scheme was designed to furnish a system of trunk line communications providing comprehensively for the whole country, and included long distance service not hitherto supplied by the private telephone administrations. The backbone system consisted of conductors of 800 lb. per mile for the longest and most important circuits,

such as London-Glasgow, London-Leeds, Leeds-Glasgow, Leeds-Carlisle and Belfast-Dublin, 600 lb. per mile for the secondary circuits, *e.g.*, Cardiff-Birmingham-Newcastle, Liverpool-Glasgow, and 400 lb. per mile for the shorter circuits, London-Ipswich, London-Brighton, etc. The scheme provided for the use of aërial conductors throughout, and underground sections were kept to an absolute minimum. Most of these lines were in service prior to the acquisition by the Post Office, in 1896, of the privately owned trunk telephone system.

Included in the Postmaster-General's scheme for the provision, by the Post Office, of a comprehensive trunk line system, embraced by the Parliamentary Bill introduced in May 1892, was a proposal for establishing telephonic communication between Great Britain and Ireland, by a telephone line connecting Glasgow with Belfast, including a submarine cable across the Irish Sea. The cable was eventually laid between Port Patrick, in Scotland, and Donaghadee, in County Down, and by its means facilities were afforded, not only for direct communication between Glasgow and Belfast, but also, at a later date, upon completion of further trunk lines, for extension of the range of communication afforded by the cable as far as Dublin and Cork in Ireland, and, in Great Britain, to Manchester, Liverpool and Leeds, and eventually to London over lines either under construction or in contemplation. Lord Kelvin was amongst the first to speak between Belfast and Glasgow over the new cable which was opened for public use on April 5th, 1893. The line between Glasgow and Belfast was reported to have cost about £20,000.

The network of telephone trunk wires erected by the Post Office as a result of the Treasury Minute of May 23rd, 1892, was, on Wednesday, June 12th, 1895, formally inaugurated by the Lord Mayor of London at the Post Office, St. Martin's-le-Grand, when he conversed with other Municipal dignitaries at Glasgow, Edinburgh, Belfast and Dublin, and on Tuesday, July 16th, 1895, the system was thrown open for use by the public. The distance from London to Dublin was 467 miles.

Although the date appointed for the transfer of the National Telephone Company's telephone trunk line system to the State was April 4th, 1896, the transfer was not generally effected on that date, but was spread over a protracted period, during which the requisite provision for the accommodation of the company's

trunk lines was in hand by the Post Office. The National Telephone Company's trunk circuits in London were transferred from the company's Oxford Court Exchange to the General Post Office (West) on April 4th, 1896. The circuits thus diverted numbered only 33. The transfer of the whole of the trunks in the country was not finally completed until February 6th, 1897, when the transaction was completed by the company handing over at Manchester and Liverpool the last of their trunk lines.

The diversity of opinion which existed in 1892, upon the policy which should be followed relative to the telephone question, is commented upon in Chapter XXI. The advocates of competitive and Municipal telephony were apparently obsessed with the erroneous idea that competition was essential to effective and successful development of the telephone service, in spite of the duplication of plant which inevitably must ensue from such a policy, and the difficulties of intercommunication between rival systems; also that the proper authority to undertake successfully the local service was the local or municipal authority, which, as pointed out at the time, had no knowledge or experience of the intricate telephone business. They were decidedly averse to the continuance of a monopoly they alleged had failed, although the failure, if such it might be correctly regarded, was largely due to the withholding of reasonable wayleave facilities. The question of wayleaves was paramount, and largely operated in turning the scale in favour of Municipalities and supporters of municipal undertakings, and of a policy intended to place the administration of the local telephone service in the hands of local authorities and the Post Office, in competition with the National Telephone Company. The disadvantages associated with separate ownership of the local and trunk line systems, an unavoidable essential of competition, were apparently disregarded.

Prior to the separation of the two services, trunk lines and local lines were terminated in the same building and in the majority of cases upon the same switchboard. The change involved the attention of two operators in the handling of a trunk call instead of one as formerly, and consequently additional expense and delay in the operation of each call was introduced; further expense was incurred and transmission efficiency degraded by diversion of the trunk lines into Post Office trunk exchanges, and by the provision of the necessary trunk junction lines between the local

and the Post Office trunk exchanges; additional transmission losses were entailed by the extra switching apparatus introduced into the circuit for every connection. The additional establishment and administrative charges involved by dual ownership must also have increased the cost to the country of its telephone service.

The transfer of the trunk service from private control to that of the Post Office necessitated some considerable rearrangement of the trunk circuits and methods of manipulating the trunk traffic. Prior to 1896, as previously mentioned, trunk circuits were accommodated in the same building and usually on the same switchboard as subscribers' lines. The system of signalling in common use throughout the country for subscribers' local connections was that generally known as the " magneto " call and " clear," and a similar system of signalling for trunk and junction working was also generally employed, as described in Chapter XI; lamp signalling for junction circuits was introduced by the National Telephone Company soon after 1895, but the system had not developed extensively at the time the trunk lines were transferred to the Post Office.

The capital cost of trunk switching equipment, as compared with the line costs, is little more than trifling, and in view of the specially high costs pertaining to trunk line plant, it is particularly important that trunk lines should be worked to their utmost capacity, that is to say, the idle time should be reduced to a minimum. Automatic signalling is a means to this end, and therefore it was one of the features of the Post Office trunk telephone system. From the inception of its telephone system the British Post Office has always advocated, and striven to secure, the advantages which attach to automatic signalling, and when the engineers of the Post Office were confronted with the problem of devising a system for working the whole of the trunk service of the United Kingdom, automatic signalling was considered to be an essential and the system eventually devised possessed many original features peculiar to the Post Office.

An exhaustive description of the methods of trunk working adopted by the Post Office will not be attempted, and its principal features merely will be outlined. For further and more detailed information reference may be made to the text-books dealing

with the subject, in particular Mr. T. E. Herbert's " Telephone System of the British Post Office."

On November 12th, 1896, that is, shortly after the acquisition of the trunk lines by the Post Office, a paper was read by Mr. J. Gavey before the Institution of Electrical Engineers entitled " Telephone Trunk Line System in Great Britain "; the elimination of inductive disturbance on long lines was discussed and the methods of trunk switching initially adopted by the Post Office were described.

In the design of the switching system, the Post Office had to provide for four distinct conditions, viz. :—

(1) Trunk to trunk connections.

(2) Connections between trunk lines and subscribers of the National Telephone Company.

(3) Connections between trunk lines and subscribers to the Post Office system.

(4) Connections between Post Office subscribers.

To provide for communication between the Post Office trunk exchanges and subscribers to the National system, trunk junction circuits, generally equal in number to the total number of trunk circuits concerned, were installed.

In the smaller exchanges it was necessary that each of the conditions named should be fulfilled on one switchboard and for large exchanges specialisation in operating was desirable.

Switch sections of uniform size and design, but with three distinct arrangements of equipment, were therefore provided for as follows :—

A. Sections for small exchanges in which accommodation was afforded for trunk lines, trunk junction lines to National Exchanges and for Post Office subscribers and call offices.

B. Sections for medium sized exchanges.

C. Sections for large trunk switching centres where it was economical to accommodate Post Office local subscribers, call offices, etc., on a separate section.

The chief features of the circuit arrangements associated with the early Post Office trunk telephone system are shown in Fig. 163.

(*a*) Represents the line circuit connections of a trunk line,
(*b*) shows the line circuit connections at the Post Office end of the trunk junctions to National Exchanges,
(*c*) shows the line circuit connections of a Post Office subscriber.

Fig. 164 gives the operators' cord circuit connections.

It will be observed that across the conductors of each pair of cords an indicator of the self-restoring type, and a " telephone

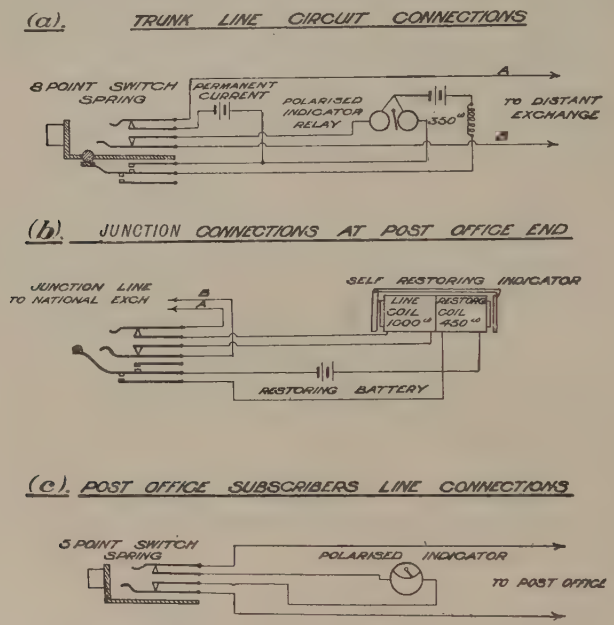

FIG. 163.—Post Office Trunk Line System, 1896.
(*a*) Trunk line circuit.
(*b*) Trunk junction line connections.
(*c*) Subscribers' line connections.

exchange galvanometer," were joined in series; the indicator was utilised for receipt of magneto clearing signals from National subscribers, and the galvanometer for battery clearing signals, on trunk and Post Office subscribers' connections. Each pair of cords and plugs was provided with a speaking key and two ringing keys, one for generator, and the other for battery ringing.

It will be observed from Fig. 163 (*a*), that, at either end of the trunk circuit, two sets of batteries were provided. The main " permanent current " batteries were of similar voltage, and were

joined to the line through the switch springs, so that the normal effect was equal and opposite, and a state of equilibrium existed. The smaller battery included in the local circuit normally deflected the needle of the " polarised indicator relay " to the right, where

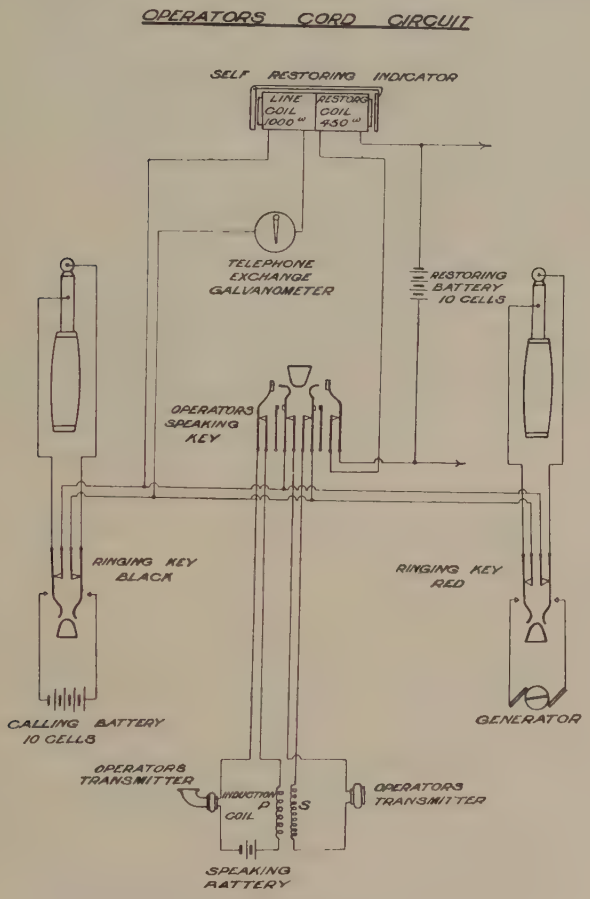

FIG. 164.—Post Office Trunk Line System, 1896.
Operator's cord circuit.

it was maintained so long as the conditions remained undisturbed. On insertion of a plug of the operator's cord circuit (see Fig. 164) into a trunk switch spring at one end of the line the local battery and the polarised indicator relay were disconnected; a circuit was completed by way of the battery and relay at the distant end, trunk line, indicator and galvanometer in the cord circuit,

and a call was denoted at the distant end by the needle of the indicator relay deflecting from its normal right hand position to the left. During the time a line was engaged the needle of the indicator relay hung vertically.

Deflection of the needle of the telephone exchange galvanometer to the right indicated the completion of a conversation between subscribers to the Post Office system, and also served as a clearing signal in the case of a through trunk line connection; when the plug at one end was withdrawn the permanent current battery was connected to line and the current from it operated the exchange galvanometer in the cord circuit at the distant end.

The self-restoring indicator was employed to denote completion of a conversation by a subscriber to the National Telephone Company's system and was actuated by operation of his magneto when " ringing off." The shutter was automatically restored by completion of a local circuit through the operator's speaking key. The calling battery of ten cells connected to the left hand ringing key was for calling Post Office subscribers and for use on trunk lines when necessary. The magneto generator connected to the right hand ringing key was for calling National subscribers. By means of the speaking key the operator's set could be thrown in bridge across the cord circuit.

After careful consideration it was decided that one operator could work five trunk circuits with efficiency; therefore each trunk section was arranged so as to accommodate five trunk lines, a similar number of trunk junction lines to the National Company's exchange, and also to the Post Office local switch if one existed.

At offices where more than ten trunk lines terminated, traffic between the Post Office and National Exchange was handled on the call wire system. One " up " and one " down " call wire were provided for each twenty trunk lines. These call wires passed through a separate telephone switch to facilitate testing, etc., and also to enable the " up " call wires to be transferred to indicators at night. For call wire working indicators were normally unnecessary and therefore were not fitted. An " up " call wire was for the purpose of passing information respecting subscribers' requirements from the company's exchange to the Post Office, where they were recorded by operators for treatment in sequence. The call wire circuit is shown at *a* in Fig. 165. The

"down" call wire which was worked in the reverse direction was similarly arranged.

If as many as from two to ten separate switch sections were necessary, intercommunication between sections was accomplished by means of transfer circuits. An independent transfer

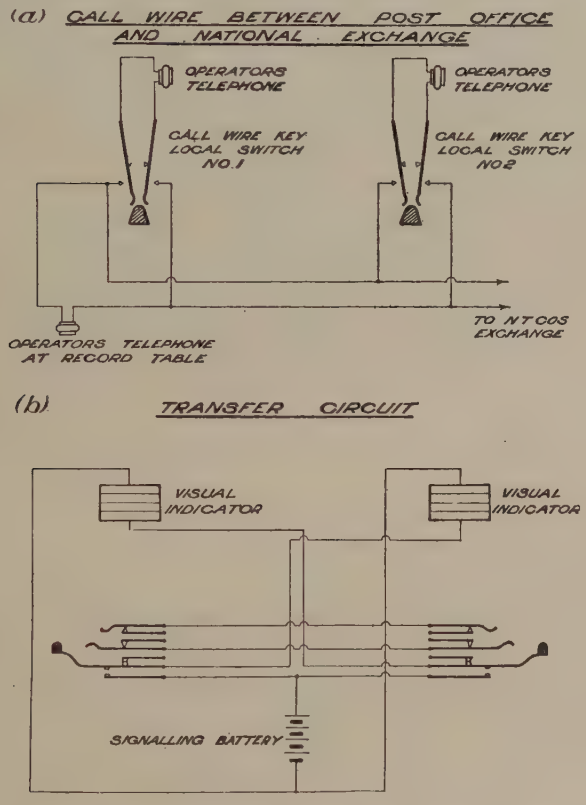

Fig. 165.—Post Office Trunk Line System, 1896.
(*a*) Call wire circuit. (*b*) Transfer circuit.

section was fitted for inter-trunk working when the number of trunk circuits exceeded fifty. In this case operators desiring connection with a trunk line terminating at another section obtained communication *via* the operator stationed at the transfer section by means of a transfer circuit. The connections of a transfer circuit between two Post Office trunk sections are shown at *b* in Fig. 165. It will be observed that the insertion of a plug

at one end operated a " visual " signal at the other. Transfer circuits between sectional switches and a transfer switch were similarly arranged and operated.

Special arrangements were made to permit of intermediate offices being connected in a through trunk circuit.

Primary batteries were at first employed except at the largest trunk centres, but the growth of the trunk system was such that the cost and maintenance of, and accommodation for, primary batteries became a serious matter, and a scheme for the universal employment of secondary cells at all but the smaller exchanges was devised and gradually brought into force.

Less than two years after the transfer of the London trunks from the National Telephone Company's exchange at Oxford Court, Cannon Street, the rapid development of the trunk service involved the installation of a new switchboard at the General Post Office. It had a capacity for 150 circuits and was brought into use on January 31st, 1898.

The trunk system of automatic signalling referred to was complete, and in theory attractive, but in practice it did not work out quite so satisfactorily as was anticipated, although it gave service for a number of years. Primary batteries were found to be inadequate to fulfil the required conditions satisfactorily, hence the introduction of secondary cells already alluded to. The complex signalling apparatus needed somewhat delicate adjustment, and under practical working conditions was not always to be relied upon. Improvements in switching apparatus and appliances were therefore taken in hand, and steps were also taken to increase the operating efficiency by systematic study of traffic problems, an important one being the increase of the proportion of time trunk circuits were usefully employed.

The telephone call wire was first introduced by the Post Office for trunk working between London and Liverpool in 1904; its use was subsequently extended to many other places where suitable groups of trunks existed, and an improvement resulted in the direction desired. The introduction of telegraph call wire working followed; the telegraph wire was superimposed upon one of the trunk circuits in the group; further improvement was effected, but the method had the objection that it necessitated the employment of a skilled telegraph operator, an objection, however, not of very vital importance to an administration

which combined telephone with telegraph working. A type of headgear sounder to be worn like a headgear receiver was evolved for this work.

The early introduction of record circuits between exchanges of the company and the Post Office trunk exchange, by which subscribers were enabled to state their requirements direct to the Post Office operator, and obviate repetition of the demand by the National operator, secured distinct and obvious advantages. The introduction of the calculograph for timing trunk calls was another innovation, and to avoid the necessity for the operator comparing the time stamped on the ticket with the time indicated by a clock, an apparatus was devised and brought into service by which the lighting of a lamp indicated that " time was up." This ingenious provision was arranged by means of an automatic time check apparatus, introduced at a number of lamp signalling exchanges; it was described in *The Electrician* for June 15th, 1906.

The expansion of the trunk service soon called for further and more comprehensive improvements in switching and operating methods, and an entirely new system was therefore evolved. The transfer system of working was retained, but lamp signalling was introduced, and the trunk junction circuits were multipled throughout; the larger groups were worked by call wire, and the smaller by automatic lamp signalling. The engaged test for the latter was applied by means of a key instead of in the ordinary way. This system was designed for the new London trunk exchange installed in the building which housed the Central Telephone Exchange in Carter Lane; it was brought into service on January 30th, 1904, and replaced the old trunk exchange at the Central Telegraph Office. This exchange was fully described and illustrated in *The Electrical Review* for February 12th, 1904, and also in *The Electrician*, and therefore needs no further mention. The transfer involved the diversion from the old premises to the new of 144 trunk circuits, communicating with 56 provincial and two foreign trunk centres, and 274 junction, record and call wire circuits, for communication between the trunk exchange and nine London exchanges of the Post Office, as well as sixteen of the National Telephone Company's exchanges.

Short accounts of the " Development of the Post Office Long Distance Trunk Exchanges System," considered from a traffic and

an engineering point of view, were given respectively by Messrs. J. Stuart Jones and W. J. Medlyn in the *Post Office Electrical Engineers' Journal* for October 1908, and an article on "Trunk and Junction Circuit Development," by Messrs. I. H. Jenkins and H. W. White, appeared in the January issue of the same journal for 1916. The latter article dealt particularly with the developments in circuit design, from the time the State commenced to administer the combined trunk and local systems in 1912. A further article referring to the telephone trunk line system, entitled, "Automatic Signalling on Telephone Trunk Lines," by J. G. Hill and C. Robinson, appeared in the *Post Office Electrical Engineers' Journal* for July 1917.

The inauguration in 1889 of the continental telephone service, which involved the construction and laying across the English Channel of a submarine cable specially designed for telephone working, and the later establishment of telephonic communication between Great Britain and Ireland by means of a similar cable, received mention earlier in this chapter. The provision of further cables between Great Britain and the Continent and Ireland was also left to the enterprise of the British Post Office, and some brief information of later developments in the provision of submarine cables for telephone purposes will therefore be added at this juncture.

The increase in the Anglo-French telephone traffic was such that in 1897 two new cables were laid between England and France, one by the British Post Office from St. Margaret's Bay to Sangatte and the other by the French administration between Grisnez and Abbot's Cliff.

Communication between the Isle of Wight and the mainland was provided by means of a submarine cable laid on June 30th, 1897. This cable was a departure, inasmuch as it was the first submarine air space cable to be laid. Its points of termination were, Stone Point in Hampshire and Gurnard Bay in the Isle of Wight, and its length was two knots. The cable was designed and patented by Messrs. Willoughby S. Smith and W. P. Granville. The results of the tests conducted after the cable was laid were considered sufficiently satisfactory to justify the use of a similar type of cable for a longer distance, and consequently, when necessity arose for augmenting the existing channels for trunk service between England and Ireland, a similar type of cable

was used. The new Irish cable ran from Nevin in Wales to Newcastle in Ireland.

The cable was designed with the object of combining the durable insulating properties of gutta percha with the low capacity advantages accruing from the use of air insulation. There were four conductors, each consisting of a centre wire of 50 mils diameter surrounded by ten wires of 22 mils diameter, making a total weight per conductor per knot of 138 lbs.

The " make-up " of the cable is shown in cross section in Fig. 162. The total length of the cable, laid in 1898, was 57·123 miles. From the outset the cable was not a success, owing to serious overhearing between the two circuits, and, although numerous experiments were made with a view to remedying the trouble, it was in 1902 abandoned as a telephone cable, and has since been used for telegraph purposes.

Facilities for telephonic communication between London and Brussels were afforded in April 1902 by the laying of a cross-Channel cable between St. Margaret's Bay and La Panne in Belgium. In view of the failure of the Irish air space cable and the success of the original Anglo-French cable, the latter type of cable was adopted and satisfactory speech was obtained. Its length was 47·3 knots. An attempt made in 1901 to afford similar communication was unsuccessful owing to failure of the submarine cable.

The adaptation of the Pupin coil to submarine telephony began with a cable laid in May 1910 across the English Channel, for the purpose of supplying improved telephone facilities between England and France arising out of the increased public demand for telephone service between the two countries. Messrs. Siemens Brothers manufactured and laid the cable between Abbot's Cliff on the English side and Cape Grisnez in France, the cable ship " Faraday," assisted by H.M.T.S. " Monarch " being employed for the purpose. H.M.T.S. " Alert " laid the shore ends. A full description of the design and laying of this cable was given by Major W. A. J. O'Meara, C.M.G., in a paper read before the Institution of Electrical Engineers on December 15th, 1910.

A French cable continuously loaded was laid between the same two points in 1912.

A further departure in submarine cable practice was launched with a cross-Channel loaded cable laid in August 1911 between

St. Margaret's Bay and La Panne in Belgium. This cable was a distinct advance on the previous loaded cable laid between England and France in 1910. Gutta percha, previously used as dielectric in the successful underwater telephone cables, possessed satisfactory insulating properties under ordinary conditions, but when considered in relation to high frequency telephone currents, there was considerable room for possible improvement in securing a reduction in the comparatively high leakance. In order to reduce the value of $\frac{S}{K}$, which, for gutta percha, was of the order of 120, and to produce a dielectric more suitable to the requirements of telephone transmission, Messrs. Siemens Brothers, possessing considerable experience in the manufacture and laying of submarine cables, specially investigated the problem, and were eventually successful in producing a form of dielectric in which the value of $\frac{S}{K}$ was reduced to a point as low as 20, a figure actually comparing favourably with air space paper cables in this respect.

Messrs. Siemens' production, which is protected by patent, involves the use of " balata " subjected to treatment by a patent process, to give it the requisite low leakance. Balata, which has been used in conjunction with gutta percha for many years, is a gum possessing many features in common with gutta percha, and is procured in a similar manner, but from a different tree, viz., the *Mimusops balata* tree, which flourishes in British, French and Dutch Guiana, Honduras and Brazil.

This form of dielectric was first adopted in the new Belgian cable with perfectly satisfactory results, and its use has therefore been continued in all submarine loaded cables since laid for the British Post Office. As a result of experience, however, cables are terminated at the shore ends by a half knot length of cable insulated with gutta percha, as gutta percha is less subject to deterioration when exposed to air.

The two pairs of conductors contained in this cable were composed of copper strands each 36 mils in diameter. The total length of the cable was 47·9 knots, and the loading coils were spaced at intervals of one knot. The coils were arranged to permit of phantom working, and by this means the derivation of an additional circuit out of the two physical circuits was possible.

The completed cable had an approximate transmission equivalent of $8\frac{1}{2}$ miles of standard cable. It was manufactured and laid by Messrs. Siemens Brothers, the cable ships "Faraday" and "Helmsman" being employed in the operations of laying.

In December 1913 a loaded cable between Nevin, North Wales and Howth, near Dublin, was laid across the Irish Sea in order to improve transmission between towns in England and Ireland, and, in particular, to afford satisfactory communication between Ireland and the southern half of the United Kingdom. At the time of laying it was the longest submarine loaded cable laid by the Post Office, and was nearly 64 nautical miles in length. The cable was of similar design to the Anglo-Belgian cable laid in 1911; a cross section is given in Fig 162. The 3-wire strand of the outer sheathing was included in order to indicate that the cable was a loaded one, in the event of it being picked up for repair.

The cable was manufactured by Messrs. Siemens Brothers at their works at Charlton, Woolwich, and was laid by H.M.T.S. "Monarch." The land line connections to this cable for Manchester and Dublin were composed of open wire of 600 lb. per mile weight.

A paper by Sir William Noble, entitled "The Long Distance Telephone System of the United Kingdom," read before the Institution of Electrical Engineers on March 17th, 1921, gives particulars of Submarine telephone cables laid in the period intervening between 1910 and the date of the paper.

The inferiority in transmission efficiency of cable conductors, as compared with open wires, for a long time precluded the use of the former for long distance circuits, and the advantages accruing from the employment of conductors entirely shielded from climatic influences was therefore denied the trunk service. The transmission losses of underground conductors were indeed of such serious proportions that even short sections of underground cable were studiously avoided. Considerations of transmission demanded, therefore, that long distance lines should be composed of open wires and the employment of underground cable for trunk purposes was, for many years, limited to short sections through the more congested centres of large towns and cities, where overhead lines were impracticable.

The earliest cables for accommodating trunk circuits for short

distances underground through or into towns were of the same class as those used up to that time for underground telegraph lines and were composed of copper conductors weighing 40 lbs. per mile, insulated to an overall diameter of 174 mils with 50 lbs. of gutta percha. In 1891, when dry core cable was introduced, the development of the telephone trunk system did not call for the use of much paper-insulated underground conductor, but eventually dry core cable was utilised generally where the use of underground conductors could not be avoided. Such cables possessed no features of special mark. Usually they contained conductors of comparatively heavy and of composite gauge.

The introduction of the Pupin loading coil, which, under favourable conditions, improved the efficiency of underground conductors by three to three and a half times, a most satisfactory improvement factor, relieved the situation somewhat, and extended the field for use of underground cable for trunk circuits. The advantages to be derived from the use of underground conductors were quickly applied in the provision of numerous intertown underground cables of comparatively short length. The introduction of loading also operated to effect economy in the cost of copper in new underground construction.

A noteworthy example of the early application of loading on comprehensive lines, to the long distance service, was in the London-Birmingham-Liverpool loaded telephone cable completed in 1915–1916. The cable contained two 300 lb., fourteen 200 lb., twelve 150 lb., and twenty-four 100 lb. metallic circuits, assembled in multiple twin, 4-wire core formation. It was loaded at $2\frac{1}{2}$ mile intervals. The London-Birmingham section of the cable was manufactured and laid by the Western Electric Company, and the Birmingham-Liverpool section by the British Insulated and Helsby Cables, Ltd., the former firm supplying the whole of the loading coils. Particulars of the scheme and the results obtained with the completed cable are given in articles which appeared in the *Post Office Electrical Engineers' Journal* as follows :—

" London-Birmingham-Liverpool Telephone Cable," an article by W. J. Hilyer, April 1914.

" London-Birmingham Loaded Cable; Results obtained in the Final Tests," by " J. G. H."

" London-Birmingham-Liverpool Loaded Cable. Results ob-

tained in the Final Tests of the Birmingham-Liverpool Section," by " J. G. H."

The production of an appliance for relaying or repeating telephonic speech in much the same manner as telegraphic signals are commonly repeated has been the dream of telephone engineers ever since the earliest days of telephony, and numerous devices were from time to time invented, and in many cases patented, for that purpose before success was finally achieved. The story of the telephone repeater is a history of some length in itself and cannot be treated adequately in this volume. It is a story in which numerous investigators, who have laboured patiently upon the problem, are concerned and one in which failure after failure has been experienced. For the most part attention was directed towards the production of a repeater electro-mechanical in principle, and many of the devices invented have consisted essentially of an arrangement of some form of telephone transmitter and sensitive receiver in combination. Frequent and patient trials of the products of numerous inventors have been made from time to time, and in spite of the extreme delicacy of the electro-mechanical apparatus devised and of its adjustment, some promising results were obtained and moderate success under commercial conditions was actually secured. In view, however, of the extremely small energy and variable frequency of telephonic speech currents, the production of a really satisfactory electro-mechanical repeater presented insuperable difficulties.

The transmission of telephonic speech from end to end of the country by means of underground conductors has at last been rendered possible by the evolution of a telephonic repeater, in which an adaptation of the vacuum oscillation valve, invented by Professor Fleming of London University, is the essential feature. The production of a satisfactory telephone repeater is a modern development of telephonic science recently accorded a good deal of attention in the technical Press, and therefore needs no further description here. It bids fair to revolutionise the trunk line system of the country; an elaborate scheme is now in process of execution for the provision of a long distance telephone system embracing the whole of the country; it is composed exclusively of underground conductors of comparatively light gauge, loaded at intervals of approximately 2000 yards, linking up repeater stations situated approximately 50 miles apart. Thus the one

time medium of telephonic transmission, the simple metallic loop, is assuming a different and more complex form, and is becoming, as it were, more and more assimilated with the speaking apparatus proper. In the near future, therefore, a comprehensive long distance underground telephone system, immune from those sources of interruption and disaster to which even the best constructed overhead lines must ever be subject, will no doubt be available.

The application of the telephone repeater to the long distance telephone system of this country was dealt with in a paper entitled, " The Long Distance Telephone System of the United Kingdom," read by Sir William Noble, then Engineer-in-Chief to the British Post Office, before the Institution of Electrical Engineers, on March 17th, 1921.

The author cannot do better than conclude this chapter on Long Distance Communications by reference to the Inaugural Address delivered before the Institution of Electrical Engineers by the President, Mr. Frank Gill, O.B.E. on November 2nd, 1922.*

The greater portion of that address was devoted to Electrical Communication, upon which subject Mr. Gill is a well known authority, and particularly to telephony over considerable distances. Problems of modern long distance telephony, in relation to their application to the Continent of Europe, were exhaustively discussed, and the elements of a scheme for the creation and maintenance of a comprehensive system of European International communication by telephone were propounded. Enlightening comparison was made between long distance communications already in daily use in America and similar useful distances which might be covered in Europe.

Some may hold the view that the obstacles in the way of international telephonic communication in Europe preclude the successful establishment of such a service, but it must be remembered that the nucleus of a system similar to that advocated by Mr. Gill already exists in the comparatively short distance lines which stretch from this country across the Channel, and between certain places on the Continent. Furthermore, although the demand for communication between the principal cities and towns of Europe may not be readily apparent, nevertheless it is a singular fact that wherever such communications have been rendered

* The *Journal of the Institution of Electrical Engineers* for December 1922.

FIG. 166.—Typical Post Office Telephone Trunk Line with "A" Poles, 1896.
(From a photograph by the author.)

[*To face page* 502.

FIG. 167.—Typical Post Office Telephone Trunk Line "H" Pole, 1910.

(*From a photograph by the author.*)

[*To face page* 503.

possible by the provision of one or a small number of lines, the traffic almost immediately has been forthcoming, the lines quickly becoming fully loaded and justifying the provision of additional circuits.

During the course of his address Mr. Gill made the definite suggestion that the telephone authorities of Europe should hold an early conference to study in detail the problem and endeavour to find a solution.

Mr. Gill subsequently lectured on the subject before the Newcastle and Gateshead Incorporated Chamber of Commerce at the Guildhall, Newcastle-on-Tyne.

Early in 1923, apparently acting upon Mr. Gill's suggestion, M. Paul Laffont, Under-Secretary of State for Posts and Telegraphs, convened at Paris a preliminary Technical Committee to consider the question of European Long Distance Telephony. Experts representative of Great Britain, France, Italy, Belgium, Switzerland and Spain were appointed to attend and the committee's deliberations lasted from March 12th to 20th, 1923. Their unanimously adopted recommendations were approved by the Administrations of the six countries represented and were published as a report in the issue of the *Annales des Postes, Télégraphes et Téléphones* for September 1923.

Thus the first step towards the consummation of Mr. Gill's scheme has been taken, and it remains to be seen what the result will be; the question as to whether the proposal becomes a reality or not will largely rest with the commercial magnates of the countries concerned, to whom the international service would most appeal.

Mr. Gill concluded his address with the following pregnant paragraph :—

"One way of increasing goodwill among nations—especially necessary to be encouraged by all means possible at the present time—is by greater and ever greater intercommunication by all methods. In the telephone we have the most perfect means of communication of which we know, immediate and perfect human speech with all its tones and inflections, and the ability by interchange of conversation to remove misunderstandings. If only we will use it, not alone will it benefit the industry of the nation, but we shall be making a definite step towards reducing the international jealousies and fears and increasing the goodwill without which there cannot be peace on earth."

CHAPTER XIX

DISTRIBUTION

By the term distribution as employed here in relation to telephony is meant the mechanical arrangement and apportionment of the various wires which are essential in any local telephone system.

The telephone systems of our towns and cities are individually of such dimensions to-day that the question of distribution, embracing as it does consideration of by far the most costly part of the plant requisite for affording telephone communication, has grown to be one of paramount importance and therefore deserves independent treatment in this volume.

The distribution of commodities such as water, gas and electricity possesses certain features in common with the distribution of telephone service, but associated with the latter are certain distinctive features which render the problem quite a different one. The fundamental difference between the distribution of gas, water and electricity and of telephone service, considered in relation to the plant which serves as the medium of transmission, is that in the three former mentioned, one main invariably serves a considerable number of consumers and, within certain limits, overloading may therefore be resorted to without very noticeable results, whereas each telephone exchange subscriber must be provided with a permanent and independent circuit, the requisite electrical constants of which must be maintained at a satisfactory standard. Furthermore, the supply of water, gas and electricity is almost universal, service being required, usually without exception, into every building which exists, or will subsequently be erected, and such conditions are, therefore, comparatively easy to satisfy.

In Telephony, circumstances are entirely different and territory to be served telephonically varies greatly in its requirements. In the commercial quarters of large cities the telephone requirements and density of subscribers' lines are greater than in other

localities; in any one building the number of subscribers may be small or great and is subject to appreciable fluctuations from time to time. In shopping quarters, not every establishment needs, or rather let it be said subscribes for, a telephone, while some rent one, and some several lines. In some only of the high class residential neighbourhoods of this country is the supply of telephone service universal to every house, and in working class houses it is the rare exception that a telephone may be found; between these two extremes range a series of classes of residential property in which the proportion of houses to be telephoned varies considerably. Furthermore, the telephone not being regarded, at any rate in this country, as a public necessity, in the same way as water, gas and electricity, fluctuations in service are constantly occurring owing to changes in ownership and occupancy of premises, alterations in the state of trade, and variations in industrial occupation. Complications are also introduced by the fact that the demand is not invariably for exchange service, and that such miscellaneous circuits as private lines and extension lines, the demand for which cannot possibly be foreseen, are frequently required at short notice and at small cost. These circumstances all combine to effect in a peculiar manner the design of an economical system of telephone distribution, and introduce difficulties of no mean order.

The above remarks present the aspect of telephone distribution in this country at the present day, when extensive underground cable systems are a commonplace. Before the advent of the telephone underground cable for general use, when in the early days overhead conductors were almost exclusively employed, such problems did not arise.

The early telephone administrations had little if any conception of the growth of the telephone service which has since taken place, and therefore they were unable to plan their line plant beforehand, with due provision for the needs of the future. They were severely criticised and censured for the erratic course which, to those without full knowledge of the circumstances, their wires apparently followed, and were accused of erecting them without any guiding principle, and without system, but the conditions under which the early development of the telephone was conducted were such that it is difficult to see what other course could have been adopted.

Open wires threatened to increase in London to a dangerous extent, but fortunately aërial cable came to the rescue and quickly came into extensive use. In the large provincial centres of commerce and industry also, before any comprehensive underground systems were established, overhead plant grew to an extent in those days by some considered alarming. Lines of all descriptions developed with mushroom-like growth, until masses of overhead wires adorned almost every town where the telephone flourished. Wires secured to chimneys, supported by roof ridges, on poles fixed in the ground, or on standards or other structures, erected on the roofs of buildings, rapidly appeared. Huge H poles and roof standards of from one to even as many as five uprights in course of time supported the many wires and aerial cables erected in the larger towns and cities, until the outcry against such monstrosities as they were regarded became universal. The difficulty of finding further suitable accommodation, the disadvantages of overhead conductors, and the public agitation, which became general, all contributed to hasten the introduction of underground circuits.

Before the evolution of any comprehensive system of distribution was rendered possible by the advent of dry core cable in 1891, the telephone administrations were heavily handicapped in the provision of underground wires by the absence of types of cable eminently suited to telephone conditions. Earliest relief was afforded by means of gutta percha-insulated wires. They were bunched together in the form of a cable and drawn into cast iron or other suitable pipe; they were usually bound together to compact them into as small a space as possible, to facilitate the drawing in operation, and to protect the outermost wires from abrasion. Such cables were generally utilised to afford relief to the main lines of route radiating from exchanges; they were terminated at a suitable point and the overhead route continued beyond as before. With this type of cable only a comparatively small number of subscribers lines could be accommodated in the three-inch pipe then commonly used, but as it was the only satisfactory method available, it was employed where underground work was for any reason imperative.

Multi-wire cables of several descriptions were tried with varying results, and cables accommodating as many as 150 wires in one pipe were employed prior to the appearance of the dry core paper cable.

The practice of affording relief to the heavy main lines in the immediate vicinity of exchanges continued, until an exchange line system generally consisted of cables containing as many conductors as it was practicable at that time to accommodate in one pipe, radiating from the exchange to terminating poles from which overhead lines continued, the number of overhead wires gradually tapering as subscribers' lines were led away from them. Before the introduction of paper core cable, 150 wire cable was considered large, and one or even more such cables were sometimes terminated upon one structure. In this manner the territory in the immediate neighbourhood of exchanges was cleared of all overhead wires except those required for serving subscribers whose premises were situated therein, and provision was also made for further development.

The introduction of dry core cable in 1891 marked the commencement of a new era in telephone line distribution, and solved many of the technical difficulties associated with the provision of underground telephone circuits. As experience was acquired, improvements in design and manufacture followed, until in 1896 cables accommodating as many as 153 pairs of wires were produced. Although these, the largest cables manufactured at that time, were small as compared with the largest present-day cables, they contained too many pairs generally to be terminated at one pole, and consequently branching cables were installed, distribution still being completed on the outskirts by means of bare wires carried on lengthy overhead routes.

The number of pairs in telephone dry core cables was quickly increased to 204, and it soon became necessary to give more particular attention to the general lay-out of underground plant. One of the earliest problems was the determination of the number of ducts to be arranged for when underground schemes were contemplated, and also the ratio which the initial number of working wires to be accommodated should bear to the size of cable to be laid. Such was the development experienced that, so far as the latter question was concerned, it was usually a sound proposition to instal main cables of the largest size available, and the branches generally amounted in the aggregate to a number of pairs equivalent to those of the main.

The increased demand for dry core cables was quickly followed by improvements in manufacture, and a reduction in cost, with

the result that a policy of increasing the number of branch cables or distributing points, and decreasing the number of wires therein, was found to be economical and was adopted; at this juncture the fundamental problems associated with present-day cable distribution became more or less crystallised, and were studied scientifically.

Past experience, although not to be despised, could not be relied upon entirely as a guide to future practice; the telephone development which might be expected was more or less a matter of imagination, and the prospect of further improvements made to dry core cables was so uncertain, that decision as to the number of ducts, and sizes of cables to be installed, could not be based upon any very sound or satisfying rule or method. During the whole history of the telephone, technical development has been so rapid that, time after time, engineering policy has been entirely upset and has had to be modified frequently; schemes for underground cabling were no exception and the principles of design of cable systems were subject to successive revision.

It will be clear that in any telephone system a certain amount of capital must be expended in order to provide plant for the requirements of the future, and a prominent feature associated with the preparation of schemes for underground plant is the determination of the class and amount of plant to be provided for future development. At all times the line plant associated with any telephone undertaking has represented something more than fifty per cent. of the total capital outlay involved, and the importance of careful design and lay-out of this costly plant, in order that the most economical arrangement may be secured, will be apparent. To keep the capital investment in such idle plant to a minimum without involving inordinate expenditure in other directions, and without introducing delays in furnishing new service in the future, is a problem which has constantly occupied the minds of telephone engineers.

Owing to the much superior development of the telephone experienced in America to that in any other country in the world, American telephone engineers were the first to be faced with the larger problems associated with distribution, and they have reduced almost to a fine art methods for computing as accurately as it is possible to determine the plant which should be provided to meet the needs of the future. A most important part of this

procedure is the forecasting of the number of subscribers who will require service in future years, and Americans have carried to perfection methods for constructing these forecasts which they have termed "Commercial Surveys," and which we, in this country, know as Development Studies. Similar methods have been introduced in this country, but owing to its inferior telephone progress, development studies have not been carried to such a fine point of determination or elaboration as obtains in the United States.

As development progressed, the density of subscribers increased, and the correspondingly larger number of wires required caused a slow but progressive diminution in the extent of the area it was economical to serve from one distributing point. The cost of cable plant decreased and the tendency was for the number of branches connected to one main cable to increase, and, in course of time, as larger main cables were manufactured, the number of branches fed from one main was multiplied. As the areas of distribution decreased in size the position, in relation to the area to be served, of the point from which distribution by means of open wires was finally effected became more central, until eventually the more densely populated areas were served from distributing points centrally situated, and only on the outskirts, where the area of distribution extended outwards more or less indefinitely, were the distributing points placed at that side of the area nearest to the exchange.

For purposes of development it was necessary to provide a number of spare pairs for each distributing point, and the aggregate number of spare pairs in main cables became a serious question to be reckoned with, and a problem deserving careful attention and consideration. Various measures were suggested which had as their ultimate object the postponement to the latest date possible of the provision of spare cable plant.

Before telephone exchanges were opened, the whole of the business of the telephone companies was the provision of private lines. A system of intercommunication becoming established, the private wire business declined and although encouraged because no Government royalty was payable in respect of the receipts derived from it, the proportion of private wires to exchange lines gradually decreased until a fairly constant relationship between the two was reached, which for a long time past—

except in some special localities—has not varied very far beyond the limits of five and fifteen per cent. Nevertheless, the private wire, including the exchange extension line, has still to be taken into consideration and therefore is a factor which enters into the design and lay-out of cable systems and the provision of cable plant. Exchange lines which, for many years past, have preponderated, all radiate from a definite centre, the exchange, whereas private lines may extend from any point to any other point, according to the requirements of the renter. They are, therefore, a disturbing factor in the symmetrical arrangement of exchange line plant, in which they must, almost of necessity, be accommodated. Where the number of private lines, in proportion to exchange lines, is small, it is usually economical to route them *via* the exchange; in this way complications in the cable system are avoided. Where, however, the proportion of private lines is higher, they exercise a weightier effect in the design of the system, and consequently must be accorded more particular attention. From time to time various suggestions have been put forward and numerous trials have been made of measures for securing, in a cable system, some degree of flexibility; by this term is meant that property which permits of connection being afforded at short notice between any two points, and of changes and alterations being made as required, without disturbance to the physical cable system, the necessity for which frequently arises out of the fluctuations in demand for exchange telephone service.

An early practical attempt to provide a certain amount of flexibility, and at the same time to secure an economy in the provision of main cable spares, was in affording means for ready access to the cable wires at certain points of junction between the main and branch cables, in order that at short notice wires might be quickly joined through as required. The occasions when access to the wires at these junction points was required would be frequent, and therefore it was essential that the measures adopted should admit of the operation being effected at small cost.

Contrivances of various designs were adopted by some companies in the United States, and in this country in about 1898 cast iron junction boxes were introduced by the National Telephone Company. These boxes took the form of a hollow octagonal casting, provided with a cast iron lid, secured to the body of the

box by means of brass screws; at the points of contact of box and lid the surfaces were machine planed, and a rubber washer, through which holes were punched, coincident with the holes in the lid and box, for reception of the screws was interposed in order to render the arrangement perfectly air and water-tight. Screwed into the sides of the box were brass linings, to which the sheath of the lead-covered cables passing through them into the box might be plumbed. An illustration of one of these boxes, some of which are still in use, appears in Fig. 168.

These junction boxes did not entirely fulfil expectations. When carefully fixed, and after test under air pressure, they might be left with safety, but after frequent openings the joint between lid and box became unreliable. It was also found that the ceaseless handling of the paper-insulated wires was highly detrimental to their insulation and life, and although various expedients were restored to, such, for example, as treating the wires with wax, and binding with cotton thread, it was finally concluded that paper insulated cable would not withstand such handling, and the use of these junction boxes was not extended.

In Fig. 169 attempt is made to illustrate the methods of distribution variously used in this country.

Diagram A, Fig. 169, represents the simplest form of cable distribution where the main cable tapers, or is reduced in size, as it recedes from the exchange, according to the size of the branches which successively leave it. This rigid adherence solely to the provision of circuits between the several distributing points and the exchange, renders the system non-flexible, and a circuit required between one distributing point and another can only be connected *via* the exchange, a course which entails the utilisation of excessive wire mileage.

In Diagram B, of the same figure, the actual distribution of pairs of wires is the same as in the previous case, but the main cable is of even circuit capacity throughout, an arrangement desirable in some cases from an economical point of view. The distributing points remote from the exchange may be relieved subsequently by diverting certain of those branches in nearer proximity to the exchange to a new but shorter main cable laid when the necessity arises; the wires thereby made spare in the old main may be jointed forward, and utilised for providing the additional accommodation required at the furthermost points.

This procedure has the effect of delaying the capital expenditure incurred in the installation of the second cable.

Diagram C illustrates the use of "multiple" or "teed" circuits, where as many as may be deemed desirable of the pairs at selected

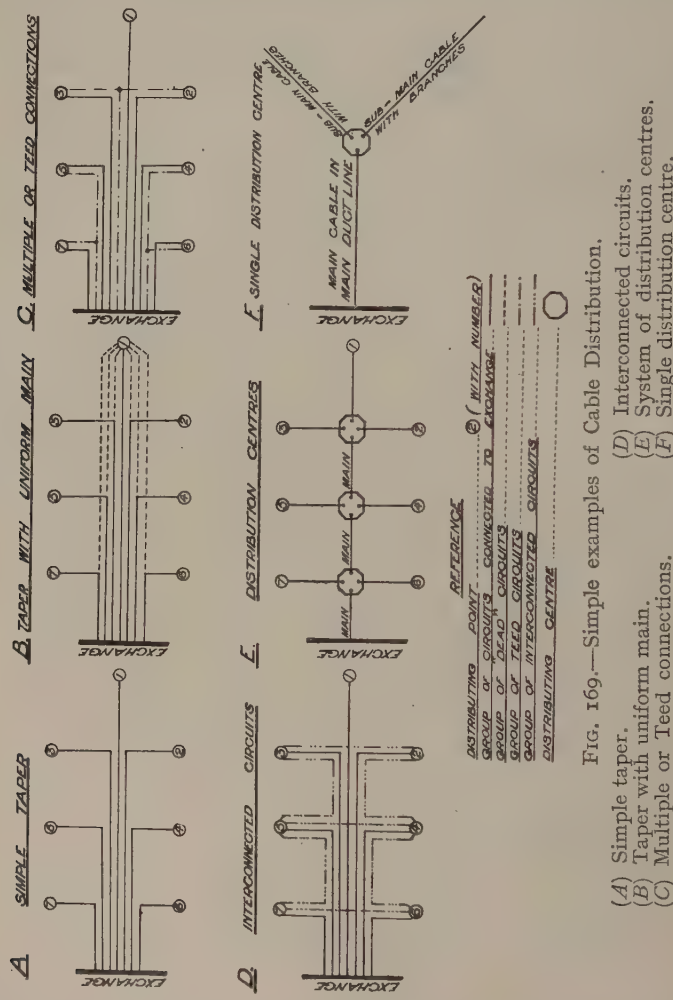

FIG. 169.—Simple examples of Cable Distribution.

(A) Simple taper.
(B) Taper with uniform main.
(C) Multiple or Teed connections.
(D) Interconnected circuits.
(E) System of distribution centres.
(F) Single distribution centre.

distributing points are connected to identical pairs in the main cable, so that they may be available at more than one point. Such wires may be utilised between the exchange and any of the distributing points to which they are connected, or between one such point and another. They are useful for party lines, but

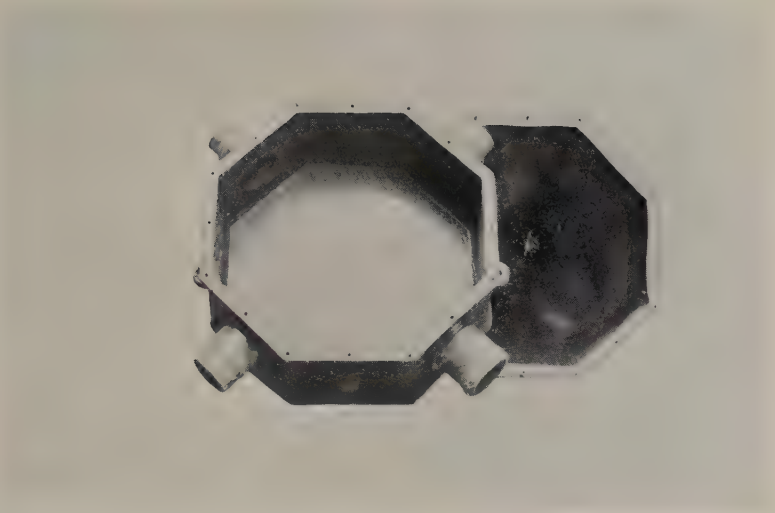

FIG. 168.—Junction Box for Underground Cables as used by the National Telephone Company.

(From a photograph by the author.)

FIG. 170.—Cable Distribution Head as used by the British Post Office in the Telephoning of London, 1901.

(From a photograph by the author.)

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possess the disadvantage that the cable system is rendered more complex, and that faults are liable to arise at the dead, or spare, ends.

Another means for providing flexibility without disturbing the permanent jointing system is illustrated in Diagram D of Fig. 169, which exemplifies the use of certain circuits interconnected directly between one distributing point and another. They may be utilised for private or extension lines, party lines, and to a certain extent for relief of any distributing point, connected to another, where the direct circuits have become exhausted. Although the flexibility secured by this arrangement is sometimes convenient, the system has the objection that the distribution is complex, and that it is difficult to predetermine the number and arrangement of interconnected circuits.

The most flexible system possible is indicated by the example at E of Fig. 169, where distribution centres in the form of junction boxes are provided at each point of junction of branch and main cables. These junction boxes, previously alluded to, veritably constitute a cross connecting medium at the crucial points indicated, and by their aid any required combination of circuits is possible at short notice. While the system is primarily flexible it suffers from the disadvantages already detailed.

Another arrangement for deferring capital expenditure in cable plant is exemplified at F in Fig. 169, where one large main cable along the main duct line is connected to two lateral sub-main cables at some distance from the exchange; the aggregate circuit capacity of the two sub-mains is greater than that of the prime main, and the latter when full may be relieved by the provision of a second, similar and parallel, cable.

The explanatory diagrams referred to are of the simplest possible form and for the purpose of illustration only. They are in no way indicative of actual cases. An 800-pair cable may have thirty or more distributing points connected to it, and the economical distribution of circuits in such a system is not as simple a matter as it may appear. In any cable system a combination of two or more of the methods illustrated may be, and has been, employed, with the object of securing the most economical and serviceable arrangement.

All the methods indicated were employed to varying extents by the National Telephone Company. As previously stated,

the use of junction boxes was not extensive, owing to the disabilities they suffered, and the use of teed and interconnected circuits was also limited. The general system of distribution adopted by the National Telephone Company was rigid; the lead sheath of every cable being continuous throughout, without any physical break. Distribution of wires was initially arranged in careful agreement with the development forecast previously prepared, a certain percentage margin, or overplus, of pairs being usually allowed to compensate for errors. Where it transpired that divergence from the development estimates was of material extent, redistribution in accordance with the modified conditions and a remodelled development forecast were effected.

In order to avoid the disadvantages attached to the manufacture of cable of special circuit capacity for each scheme, standard types and sizes were introduced. Before the introduction of 10 lb. cable into this country in 1905, these standard sizes were composed uniformly of 20 lb. conductors, and were made up in sizes containing the following numbers of pairs :—

8, 14, 26, 52, 77, 102, 153 and 204.

These were the standard sizes adopted by the National Telephone Company; subsequently standard sizes more in keeping with a decimal notation, as indicated in the tabulated particulars given in Tables 7, 8, 9, 10 and 11 were introduced.

The aggregate telephone development for an exchange area can usually be foretold with tolerable accuracy, but as the area under consideration diminishes in size the proportionate error likely to be introduced increases. Consequently the percentage error in a development estimate for a large main cable is generally less than that for the branch cables fed by it. In apportioning the sizes of cable to be provided in any cable scheme, it was customary to allot the standard cable which contained the number of pairs nearest above the number of subscribers to be accommodated, according to the development forecast, at the date for which the cable was being planned. Owing to the smaller capital expenditure involved in the branch cables by reason of their shorter length and smaller number of pairs, it was frequently economical to adopt a longer planning period for branches than for main cable, and therefore the aggregate number of pairs contained in the branches from a main cable was often much greater than those of the main. Such additional pairs could

frequently be disposed of by judicious arrangement of teed or interconnected pairs.

By no means the least important part of the work associated with the Post Office telephone service, inaugurated in the Metropolis in 1902, was the design, lay-out and constructional details of the line system. In the City and West End of London line requirements were fulfilled exclusively by means of underground cable and covered wires installed in or upon buildings; in the suburbs and residential districts underground cables were extensively used, but where circumstances permitted overhead wires were employed for short distances to complete subscribers' services from the termination of the underground cable. Where the telephone density was appreciable, and overhead wires were for any reason inadmissible, underground circuits were employed throughout, 1-pair cables being taken into the subscriber's premises.

Having particular regard to the immensity of the Post Office telephone undertaking in the Metropolitan area and the extensive use made of underground cables, the design of the distributing system was a matter of considerable importance and one which demanded the most careful attention in order to produce a system which should combine economy with good lay-out. Particulars of the principal features of the Post Office system in London will therefore be recorded.

At the time the engineers of the Post Office commenced the design and construction of the line system, experience gained in a similar direction by other administrations in this country and abroad was available; dry core cable had been in use for more than ten years, and had become universally established as the recognised means for providing underground circuits.

Particulars of the several standard classes of cable adopted by the Post Office in 1900 are included in Table 19. The 20 lb. conductor cable was employed for subscribers, and the 40 lb. for junction circuits.

At the outset, Post Office engineers were in ignorance of the support which would be given by the public to their new enterprise, and therefore determination of a policy in regard to spare plant provision was somewhat perplexing. In order to secure minimum initial capital expenditure in spare cable plant, and to provide as flexible an underground system as possible, the use

at frequent intervals of a form of junction box, on the principle illustrated diagrammatically in Fig. 169, E, was decided upon and adopted. The Post Office pattern of junction box, known as a "cable distribution head" (not to be confused with the cable-head first used for terminating purposes), took the form of a cast iron box of superior and substantial construction, illustrated in Fig. 170, from which its design and general construction may be gathered. Six circular holes were provided for entry of cables. The adjacent faces of the cover and flanges of the box were machined to form, with the washer which intervened, an air-tight joint. The sheaths of the cables were plumbed to tinned gun metal nozzles or linings, available in several sizes, to suit cables of different diameters, fitting into the holes provided, and rendered air-tight by a leather washer compressed by a slotted ring screwed on to it. Special linings were supplied, to accommodate eleven 7-pair cables, and cast iron blanks were available to plug any holes not in use. The cover of each head was provided with two $\frac{3}{4}$ inch screwed holes, normally stopped by screwed plugs for purposes of desiccation and air pressure test. Cable distribution heads were secured to the walls of manholes by means of lewis bolts. There were originally three sizes as follows :—

Type.	External Dimensions.			No. of pairs in cable.
	Length.	Width.	Depth.	
A.	2′ 9½″	1′ 7″	7″	217 to 306
B.	2′ 3½″	1′ 5½″	8½″	137 to 217
C.	1′ 7½″	1′ 1½″	8½″	37 to 108

The methods of distribution practised by the Post Office, into which the use of cable distribution heads, of the type referred to, entered very largely, are illustrated in simple diagram form in Fig. 171.

At A is shown a hypothetical example of the method of distribution adopted for the denser portions of the Metropolis. At suitable intervals in the main line of ducts, which usually occupied a position approximating to the centre of the carriage-way, manholes were provided. In those manholes to be utilised for purposes of distribution—and in the City of London a very

large proportion are so employed—was fixed a cable distribution head through which a main cable was passed. From the distribution head 7-pair cables, laid as required, conveyed the subscribers' circuits, through branch pipes, to surface boxes situated

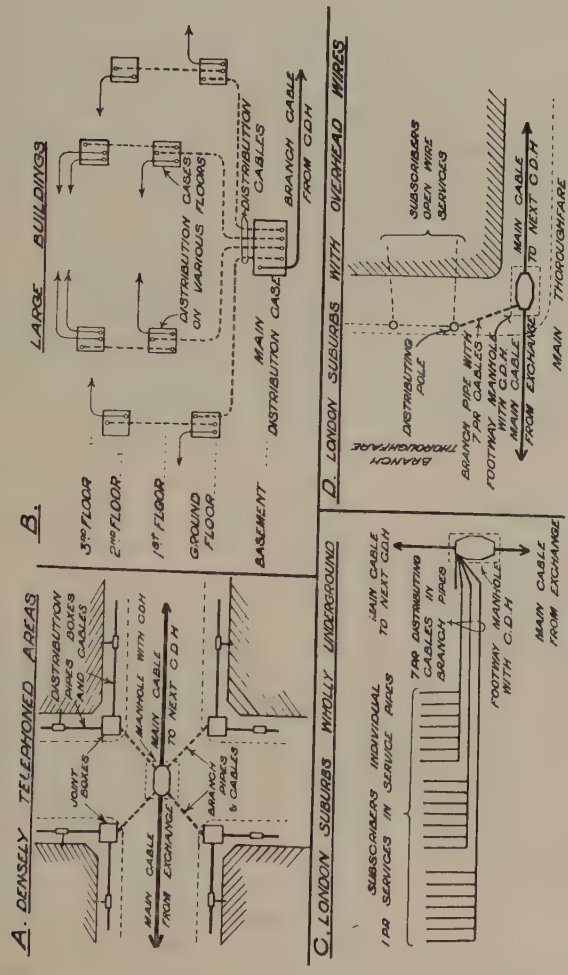

FIG. 171.—British Post Office System of Line Distribution, London, 1901.

in the footways, where 1-pair cables leading from subscribers' premises were tapped on to the 7-pair cables by means of a "solid distribution joint."

Most frequently distribution of circuits from cable heads was effected solely by means of 7-pair cables in combination with the

1-pair branches, as described, but in some cases where the number of circuits required in one building was such that the number of 7-pair cables required was excessive, larger cables were employed.

Fig. B is a simple example showing the general arrangement adopted for distributing a large number of wires throughout a large building; a large branch cable (or alternatively a number of 7-pair cables) from a cable-head terminated within a distribution case, a wooden case containing connection strips, which provided facilities for cross connection, situated usually in the basement or on the ground floor. From this case smaller cables, usually of seven pairs, rose to the upper floors and, as shown in the diagram, were terminated within smaller distribution cases from which the individual wires to the subscribers' offices were extended.

An illustrated article by the author descriptive of the cabling of large buildings in London, and entering more fully into the question than is possible in this volume, appeared in the *Post Office Electrical Engineers' Journal* for April 1914.

Fig. 171, D, which is self-explanatory, shows how open wires in combination with underground were utilised in the suburban neighbourhoods of London, and at C is given an example of the use of underground wires for the purpose of serving individually the subscribers in residential districts, where overhead wires were considered unsuitable.

At the outset the Post Office made what was considered at the time liberal provision of underground plant for the telephone development of the territory for which it provided; but comprehensive as was the original scheme of distribution, it soon became congested. Under the initial scheme of cabling, which provided that every main cable should be taken into or passed through a cable distribution head, the number of cable-heads in densely telephoned localities increased so extensively that manholes were insufficiently large for their accommodation; for this reason and also because, from a maintenance point of view, it was desirable that cable distribution heads should be used only for distribution purposes proper, and then only when necessary, their use began to be restricted by passing into them only those wires required in an area defined to be served from the point in question.

In Chapter X reference is made to the high proportion of mis-

cellaneous circuits (*i.e.*, circuits which need not necessarily be taken into an exchange) in the City of London, and the advantage afforded by a flexible cable system in dealing with them. The cable distribution heads rendered the cable system in London as flexible as it was possible to make it; they were decidedly convenient in routing miscellaneous circuits without relationship to exchanges, and avoided loading up, unnecessarily, the exchange line plant proper and the exchange main distributing frame. Since the amalgamation of the Post Office and National systems, the number of exchanges required in the centre of London has increased, is still increasing and will tend to continue to increase, and it is fast becoming more than ever an economical proposition to route, without distinction, all circuits in an exchange area, *via* the exchange which serves that area, a course which tends towards simplification of the distribution system.

In the centres of some towns the use made of open wires has been limited by the adoption of a system commonly known in this country as "block distribution" or "covered distribution" in combination generally with direct distribution underground. In the latter, cables of size suited to the requirements of individual buildings are led direct into the premises, where they are terminated at convenient points, and wires led to the subscribers' instruments as necessary. In block distribution, suitable when the telephone density is insufficient to justify the adoption of a unified system of internal distribution, cables are terminated on the external walls of buildings, from which points continuously insulated pairs of wires are distributed, as may be required, into the subscribers' offices within the block to be served from that distributing point.

Another contrivance devised by the British Post Office and employed in London for distributing small cables from a branch cable is illustrated in Fig. 172. It was known as the "Cable Union," and served the same purpose for small cables as the cable distribution head did for large ones. It was a modification of and an improvement upon the American "Hargis Splice." It provided means for distributing the circuits in a cable as large as 50 pairs, introduced into the device through the central hole in the base (shown in the plan included in the illustration), amongst a maximum of six lesser cables passed through other holes also provided in the base. The joints between wires

contained in the branch and distributing cables were disposed, as shown in the illustration, within the cover, which consisted of a cylindrical casting, closed at one end, and provided at the other with a screwed collar of brass, by means of which it was secured to the iron base of the device. The use of these

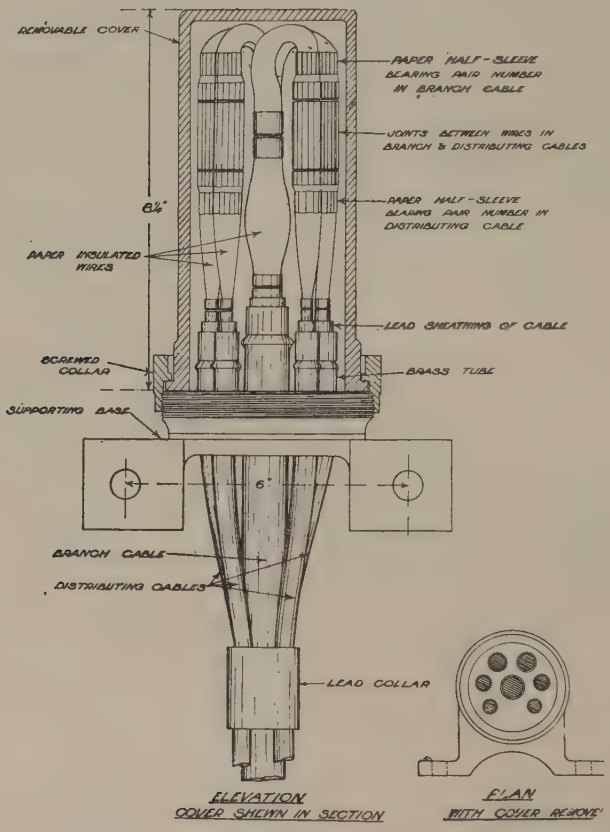

FIG. 172.—Cable Union for Distributing Circuits from small Underground Branches.

cable unions was restricted to London and was eventually discontinued owing to the difficulty of maintaining the insulation of the wires.

Questions relating to the design and lay-out of telephone line systems have hitherto received but scant literary attention, and the author is conscious that the foregoing brief descriptions of the various methods of line distribution practised since the

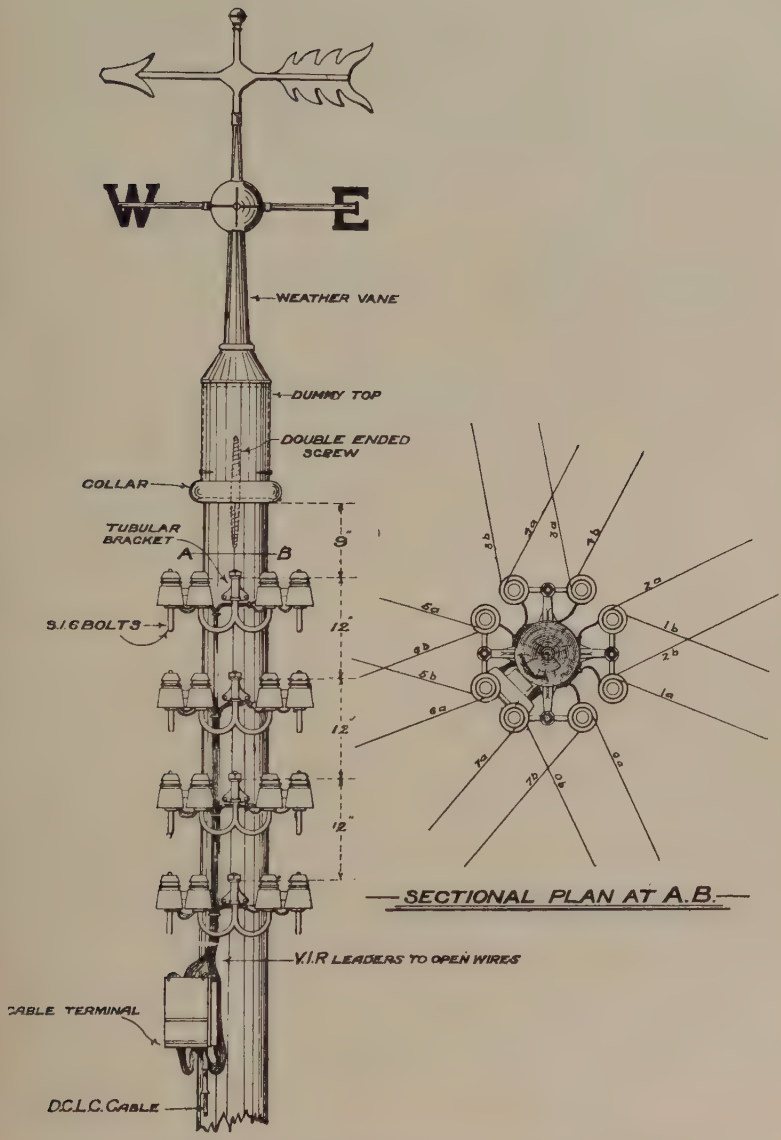

FIG. 173.—Small Ornamental Distribution Pole without Arms, fitted with Western Electric No. 14 Type Cable Terminal.

early days of commercial telephony, give but an inadequate impression of the significance and involved nature of this important branch of telephone working. This volume is devoted to the narration of history, and this fact, as well as considerations of space, preclude that exhaustive treatment which the subject merits.

CHAPTER XX

AUTOMATIC OR MACHINE SWITCHING SYSTEMS, 1879–1922

SYSTEMS of telephone switching in which the manual element for the handling of calls is conspicuous by its absence have so rapidly progressed, and increased in both importance and in number, during the past few years, that the subject of machine telephone switching has now assumed a position of real importance even in this country.

The accuracy of the term "automatic" in relation to any system in which the necessary switching is accomplished without the aid of an operator, *i.e.*, entirely by electro-mechanical devices, is open to question, but has now become so common that it is likely to be retained permanently. The term automatic is now usually intended to apply to a system whereby the actual operation of connecting one subscriber with another is effected automatically at the central exchange without any manual attention whatsoever. When the term is used in this connection, *i.e.*, in relation to the exchange, and not to the system, no objection can be taken, but it must be remembered that the satisfactory operation of an automatic system depends upon the subscriber performing intelligently and accurately certain functions which he is not called upon to do with the manual system. Therefore, considered from the subscriber's point of view, the common battery manual system is more automatic than the so-called automatic system, everything being done for him on receipt by the operator of his demands. A term which appears distinctly better than the appellation "automatic," and preferred by several telephone experts, is that of "machine switching."

Automatic telephone switching or machine telephone switching, as then, it may be more aptly termed, is so markedly different in principle and in operation, and the plant employed is so far removed in design and arrangement, from that which is used in manual switching, that it may not improperly be regarded as a

separate art. Formerly few telephone text-books devoted more than a few pages, or at most a chapter, to the subject, but now there is probably more literature available dealing with machine switching than with manual.

In this volume, it is not possible, nor would it be fitting, to attempt exhaustive description of the different systems of machine switching available to-day, and therefore a brief review only of the growth and progress of machine switching in this country will be given.

Inventive genius was applied to the production of a system of telephone switching, which entirely eliminated the human element at the switching centre, very soon after the telephone exchange became an accomplished fact. Many inventors have attacked the problem since that date and numerous devices have been designed and employed. The problem which confronts the designer of automatic telephone switching mechanism is not that of simple switching only, otherwise it would be stripped of many of its complexities, and reduced to one of comparatively simple proportions. The real difficulty lies in providing for the requirements of present day telephone traffic, that is, in disposing of the following problems :—

(*a*) The registration, metering or recording of calls.
(*b*) The elimination of ineffective calls.
(*c*) The supervision and timing of long distance calls.
(*d*) The control of unattended call office service.
(*e*) The control of party line service.
(*f*) The control of service at remote and unattended exchanges.

The first patent to be taken out in this country for an automatic switching device was that referred to in British Patent Specification No. 5114 of December 13th, 1879, in the names of M. D. Connolly, T. A. Connolly and F. J. McTighe of America. Apparatus covered by this patent was exhibited at the Paris Exhibition in 1881. Its defects were, however, such as to render it an impracticable system, but it is of historic and special interest owing to the early date in telephone history at which it was produced.

British Patent Specification No. 404 of January 29th, 1880, gives particulars of an automatic device invented by G. Westinghouse, of Pittsburg, Pensylvania. It was intended particularly

to provide for the requirements of suburban or outlying villages, where the number of subscribers was small, and the cost of maintaining an attendant prohibitive.

One of the earliest British names to be associated with the attempt to devise automatic means for intercommunication was that of Dane Sinclair, who at the time his invention was announced was engineer for the National Telephone Company's Glasgow district. The following British Patent Specifications have reference to Mr. Sinclair's inventions :—

No. 3380 of July 7th, 1883 : D. Sinclair.
No. 5964 of December 31st, 1883 : D. Sinclair and J. L. Corbett.
No. 8541 of June 3rd, 1884 : D. Sinclair and J. L. Corbett.

The subject of these specifications was an arrangement of apparatus whereby a telephone instrument connected to a branch exchange might be placed in connection with any other similar instrument on the system, by an operator situated at a central exchange, without manual attention at the branch exchange. Although the system dispensed with the services of an operator at the branch exchange, attention at the central exchange was provided for; therefore the system was not exclusively automatic as between one subscriber and another, calls being controlled by the central exchange operators, but it is interesting as being the first British attempt at machine telephone switching on record. The apparatus was designed for a small number of subscribers only, and some few exchanges were actually brought into service by means of this system in this country, one of them being at Coatbridge. In the museum of the Institution of Electrical Engineers, and also in the Science Museum, South Kensington, one of these early automatic appliances is preserved. Fig. 174 is an illustration of the complete apparatus from a block kindly loaned for the purpose by Mr. H. H. Harrison, of the Automatic Telephone Manufacturing Company of Liverpool. The system was described in " The Telephone " by Preece and Maier in 1889.

The first idea of utilising power as a driving agent for the necessary automatic switches seems to have arisen with T. A. Connolly, and is contained in British Patent Specification No. 5081 of October 25th, 1883. The specification relates to an arrangement in which a frame is provided with a series of horizontal bars,

each connected to the line of a subscriber, and a series of vertical bars each connected also with a line wire; the arrangement was apparently somewhat similar to the Umschalter switch idea. Metal carriers were caused to travel to and fro along the several horizontal bars and vertical bars, by means of electrically controlled mechanical appliances, and the collision, and consequent contact, between two carriers, one on a horizontal and the other on a vertical bar, at their point of crossing, constituted a connection. The carriers were moved forward by a belt and restored to normal by a sweep.

The Callender automatic telephone system, a Canadian invention, was described in British Patent Specifications Nos. 139 and 140, both dated January 2nd, 1894. Mr. C. J. Phillips, assistant engineer-in-chief to the National Telephone Company, visited America in 1898, for the purpose of examining into the merits and possibilities of the system invented by Mr. Romaine Callender, but so far as the introduction of methods of automatic machine switching was concerned nothing came of his visit.

A Russian production, the Apostoloff automatic system, was described in British Patent Specifications Nos. 11951 of June 19th, 1895; 14872 of July 4th, 1896, and 22360 of October 8th, 1896.

These two systems were not developed beyond a capacity for accommodating a small number of stations and were never employed in this country.

The history of practical machine telephone switching may be said properly to have commenced in 1889 with an invention of Almon B. Strowger, of Kansas City. From this invention the Strowger system of automatic telephony, to-day the most widely used of any machine-switching system, although several others followed, and are now its serious competitors, had its commencement.

Strowger, by vocation, was an undertaker, and it is said that he was led to devote his time to the production of means whereby the manual element in operating was to be entirely eliminated by his own unfortunate and vexatious experience with the manual system over which he transacted his telephone business.

Strowger's invention was first patented on March 12th, 1889, but his first practical switch was not constructed until the following year. It is described in British Patent Specification No. 7850, dated May 6th, 1891.

In this system five wires were necessary between each subscriber and the exchange, three for signalling, one for releasing, and the fifth for speaking. There was no rotary dial, such as that now commonly used with automatic switching systems; the necessary pulsations were transmitted by depression of a series of three keys, one of which represented units, one tens and the third the hundreds digit. Each key was depressed once for every unit denoted by the digit to be called; thus for a figure seven representing seventy the tens key was depressed seven times. The release was given by depressing the fourth key.

The contacts, or banks, as they would now be termed, were contained within the walls of a drum or hollow cyclinder; a radial arm, internal to the drum, could be made to rise by means of an axial shaft or spindle, to which it was attached, and to rotate by means of an arrangement of wheels under the influence of controlling electro-magnets, and in this way was caused to make connection with any of the contacts carried by the drum.

Strowger's next development was described in British Patent Specifications Nos. 11424 and 11426 of June 18th, 1892. In this invention, the drum-like arrangement of vertical contacts gave place to a series of contact studs, arranged horizontally in ten concentric circles of 100 contacts each. Concentric with the rings of contacts was a vertical spindle, capable of rotation, and supporting a horizontal arm, which carried a contact point or wiper for making contact with the studs. The wiper could be moved along the arm, by means of a bell crank lever, so as to engage with any of the rings of contacts desired, and the radial arm could be rotated so that any individual stud might be selected. The movements were controlled by electro-magnets, actuated by current impulses imparted to the line by a form of dial switch. Strowger's system was first applied in practice with a switch of this description, known as the " flat disc " type on November 3rd, 1892, at La Porte, Ind. The operation of this system still necessitated the use of five wires from each telephone to its respective switch.

In 1894, the brothers J. and C. J. Erikson developed an automatic switching device which differed radically from any other automatic switch designed either before or since. It was devised chiefly with the intention of overcoming one of the principal disadvantages of the earlier switch, namely, the multiplicity of bank wires. The bank wires of the Erikson switch were

composed of bare parallel wires, tightly stretched over a long wooden frame, a feature which earned for the device the name of the "Zither" switch. Above and across the bank wires were arranged a number of shafts, each carrying ten wipers arranged spirally around it. The shafts were capable of longitudinal, as well as rotary, motion, and a certain number of longitudinal steps, followed by a number of rotary steps, placed one of the wipers in contact with the required wire. The bank wires and shafts were arranged in a horizontal plane, and return to normal of both motions was accomplished by means of a spring. The system was installed at La Porte, Ind., in 1894, and was covered by United States Patent No. 540168. The capacity of each switch was for 90 lines. Selection was by common battery. The system was originally devised to operate with a line of two wires, but this intention was not realised in practice, and three wires and a common return were actually employed. The subscribers' calling device was a button keyboard, and ringing was accomplished by magneto. Although the switches proved to be good, and it was stated that subscribers were pleased with the method of switching, there was much cross talk, and it is said that the considerable trouble which arose from an apparently faulty line system militated against its use being continued. A larger 1,000 line board was subsequently designed, with switches of similar type, but was never put into use.

In 1895 the Strowger flat disc type of switch was displaced by one from which the present form has been developed, installations being fitted at La Porte, Ind., and Michigan City, Ind., the latter for 200 lines in that year. In this system the bank assumed practically the modern form, and consisted of ten rows each of ten punchings, arranged in an arc with electrose insulation clamped in a frame. The shaft was upright and was capable of both vertical and rotary movement. There was a plurality of wipers on the shaft, and an auxiliary switch to select the wipers. The magnet controlling the vertical movement of the shaft was operated by impulses transmitted over one wire, and the rotary magnet by impulses over the other wire, the circuit being completed through earth. United States Patent No. 638249 has reference to this system.

The electrose banks did not prove to be a success, owing to distortion caused by swelling and warping of the electrose insula-

tion, and to the excessive friction which resulted. Consequently Erikson designed a bank made of plaster of Paris. The spring contacts were suitably arranged in a mould, and plaster being poured in, held them in position when set. The complete bank was then dried in an oven and boiled in paraffin. These banks were first installed at Rochester, Minn., in 1895, for a capacity of 200 lines, and continued to be employed until 1901.

An important advance in machine switching was the invention in 1896 of the dial sending apparatus known as the large three wire dial described in British Patent Specification No. 809, dated January 11th, 1898, in the name of W. P. Thompson, for the Strowger Automatic Telephone Exchange. This dial earthed the "rotary" wire as many times as required for hundreds, the "vertical" wire for tens, and the "rotary" wire for units. It was reset by replacing the receiver. Instead of finger holes, as in the present form of dial, there were projecting vanes. The state of a call was indicated by the appearance, through an opening in the cover of the dial, of the words "Tel. Hunds, Tens, Units, Out." This indicator was, however, quickly abandoned as an unnecessary complication, and a centrifugal governor was soon introduced instead of a weighted pallet escapement.

The method of sending out a call direct from a device of this description has been criticised as offering more risk of error than if the call be deliberately set up by means of keys which are afterwards released. Nevertheless, in modified form the dial which was the subject of the patent mentioned is now almost universally used, and has been standardised for use in this country, and after extended trial its adoption has been fully justified.

In the first installation each switch was of capacity sufficient to accommodate the whole of the lines connected to the exchange, and a multiple of all the lines appeared in front of each switch mechanism. Obviously, the capacity of such a system was limited by the size of the multiple, and large installations were not practicable. Consequently, in 1896 work was commenced by A. E. Keith and J. and C. J. Erikson upon the design of a 1000 line system which did not necessitate the provision of switches individually accommodating 1000 lines, and the principle of grouping and trunking was introduced. There was one selector per subscriber, and 100 groups each of ten selectors, and ten

groups of 100 connectors each. The first installation in which primary and secondary switches were thus employed, and the principle of trunking embodied, was that of Augusta Ca, opened for service in 1897.

In 1897, the first experiments were made in selecting, automatically, an idle line in a group. A " nought " was introduced after the hundreds digit, 257, for example, thus becoming 2057. The introduction of the " nought " had the effect of causing the wipers to travel over contacts of all lines which were busy, but upon an idle line being found the impulsing was disconnected. Automatic trunking, based upon this system, was embodied in a 400 line system fitted in Berlin in 1899.

The 1,000 line system, previously referred to, was redesigned in 1898, and the side switch was invented in order to secure control by means of a single magnet. The coils of the motor magnets were still included in the line circuit, but were shunted. Arrangements were made for both wires of the line to be included in the switching, and the banks were arranged with three sets of terminals for each line.

Upon the expiry of the Bell patent in the United States, numerous telephone companies were floated, ostensibly for the purpose of entering into competition with the Bell Company. They were generally known as " Independent " companies, and in spite of the undesirable duplication of plant their activities encouraged, they flourished and multiplied. Many of them offered automatic service as an inducement to prospective subscribers to be connected to their system, rather than that of their competitors.

By 1898, there were no fewer than twenty-two automatic exchanges in operation in the United States and numerous others were projected.

In 1899 a factory model, with a satisfactory method of finding an idle line, without the introduction of a " nought " as before mentioned, was constructed, and the first exchange in which full automatic trunking facilities were provided was installed at New Bedford, Mass., in 1900. The system was designed for 10,000 lines, and first and second selectors and connectors were provided. Energy for speaking was supplied by local batteries, and both the called and calling subscribers' bells were rung. The operation of the dial was also modified.

In 1901, the plaster of Paris bank was abandoned. Experiments were conducted with paper, followed by hard fibre, suitably treated, in order to prevent absorption of moisture. In this year also the iron cores of magnets were enclosed within thin copper tubes for the prevention of sparking. The installation at Fall River included this improvement.

During the first ten years' progress, the Strowger switch passed through numerous stages of development, successive designs embracing many different forms and improvements upon their predecessors. The invention of the principle of trunking marked an important era in the development of machine switching, and the switch introduced in 1902 bears a close resemblance to the Strowger switch of to-day. Important improvements were introduced in a 10,000 line system installed at Chicago in 1902.

Up to 1903 the series system was employed and, in a 10,000 line exchange, there were included in the speaking circuit as many as six copper shielded relays. These were replaced by 500 ohm relays, placed across the loop in pairs. At the first selector both relays were connected to earthed battery, earthed impulses still being employed, the battery being disconnected on completion of a connection. At the connector, two condensers were introduced, one in each line. Primary batteries were still employed to supply speaking current. The final vertical impulse controlled the ringing of the station to be called. The first exchange embodying the bridging system was Grand Rapids, Mich., in the year 1903.

The trunk release system was introduced at Los Angeles in November 1904.

Up to 1904–5, the practice in America was to employ dry cells to supply transmitter current. The application of common battery working to machine switching transpired in May 1905, when the first common battery automatic exchange was installed at South Bend, Ind. The automatic exchange was arranged to work in connection with a manual exchange, and the subscribers' lines, connected to the latter, were multipled on connectors in order to provide for automatic subscribers' direct access to subscribers connected to the manual exchange. The connector circuits were necessarily much altered. Earthed impulses over one wire of the subscriber's loop were still sent, but, a few months later, a two wire common battery exchange, without earthed impulses, was installed at Pontiac, Ill.

In January 1906 Repeater working was inaugurated at Los Angeles.

The year 1906 was marked by the introduction of an important advance in machine-switching design, from which considerable economy in the capital cost of switching mechanism was secured. Up to this time it was the practice to terminate each subscriber's line on a first selector, an expensive piece of apparatus. An attempt to reduce the proportion of idle plant, and the capital cost therein involved, resulted in the production, in 1906, of a device known as the " Keith Line Switch," one of which was necessary for each line, but which cost about 20 per cent. only of the cost of a selector. By means of the Keith line switch, a reduction and proportionate saving in the number of first selectors required were made possible, one first selector serving for ten subscribers. By means of this switch, described in British Patent Specification No. 26301 of November 20th, 1906, a trunk to be requisitioned for use was selected in advance of the call, by means of a stepping master switch, which maintained all the disengaged line switches in readiness to make connection with a disengaged trunk. The switch was first operated by the momentary earthing of the " rotary " side of the line by a passing contact on the switch-hook of the subscriber's instrument. The first line switches were mounted on a cylindrical frame, and were protected by barrel-shaped canvas covers. The exchange at Columbus, Ohio, opened in 1906, was of this type.

Henceforward, developments were for some time principally in the direction of eliminating the earth return, previously essential in connection with the transmission of impulses to the switch magnets, and for effecting release of the switches upon replacement of the receiver after conversation.

The " two wire " system, in which the use of earth was entirely dispensed with, was ultimately produced in 1912. By this development, not only was the subscribers' calling equipment considerably simplified, but modifications made in the design of the exchange switches decidedly improved their operation, and rendered them more reliable. One of the first exchanges of the two wire type was Regina, Sask., opened in 1913.

On June 29th, 1908, Mr. W. Lee Campbell presented a paper to the American Institute of Electrical Engineers, entitled " A Study of Multi-Office Automatic Switchboard Telephone

Systems"; the author advocated the employment of automatic equipment in conjunction with a process of decentralisation as a means by which the cost of line plant might be considerably reduced. He pointed out that only 8 per cent. of the total number of exchange lines were engaged at the peak of the load, and contended that the cost of automatic equipment was not greatly increased, and that its efficiency remained unimpaired, by decentralisation. The costs of the manual and automatic systems were compared, and particulars of the floor space required and comparative costs of maintenance were given.

On June 29th, 1910, Mr. Arthur Bessey Smith read a paper, entitled "The Automatic Telephone in Relation to City Service," before the American Institute of Electrical Engineers, wherein improvements introduced in the San Francisco installation were described.

Modern Standard Automatic equipment was described in a further paper, by Mr. Arthur Bessey Smith, read before the American Institute of Electrical Engineers on December 12th, 1919, under the title "Applicability of Automatic Switching to All Classes of Telephone Service."

The following two published works treat of the Strowger Automatic System as it is applied in the United States :—

"Automatic Telephony," by Smith and Campbell.
"Automatic Telephone Practice," by H. E. Hershey.

The Automatic Telephone System was first introduced into the United Kingdom in 1897, when representatives of the Strowger Automatic Exchange Company of Chicago brought over to London a working exhibit of 200 lines capacity, which was installed at Winchester House, Old Broad Street, London, E.C., where the system was exhibited for the first time on this side of the Atlantic. In the system then exhibited, each subscriber's line terminated upon a switch of the step-by-step up-and-around type, and a multiple of all the subscribers' lines appeared in front of each switch mechanism.

Obviously, the capacity of the system was limited by the size of the multiple, and large installations were not considered practicable. The exhibit attracted considerable interest, but, on account of its limited capacity little progress was made.

The Direct Telephone Exchange Corporation, Ltd., with offices

at 84 Winchester House, Old Broad Street, London, E.C., was formed for the purpose of bringing prominently before the British public the practicability of the system, and for its exploitation generally in this country. The company published a well got up brochure describing the method of switching in some detail, and issued a copy of a report by Mr. A. R. Bennett, who had recently completed a tour of inspection of automatic exchanges in the United States. This report was dated October 22nd, 1898. Various technical and other journals published descriptive articles of the system, and it was shown in operation at the Royal Institution in June 1898. The automatic system referred to embodied the patents granted to A. E. Keith and J. and C. Erikson, together with several others of less importance which had been acquired.

Designs for switching equipment included what were described as the 100 and 400 line systems in which a single switch was used for each subscriber, and also exchanges for 1,000 and 10,000 subscribers in which two switches per subscriber were utilised. In the former, or smaller, exchange systems, the electro-magnets actuating the switches were included in the speaking circuit during conversation, and their resistance was therefore low. For the exchanges of larger capacity, the bridging system was employed.

The working principle and mechanism of the two were similar, but in the bridging system the electro-magnets of the switches were wound to a higher resistance, and were connected across the circuit, instead of in series.

The banks were made up of brass contact pieces assembled in a casting of plaster of Paris. Each bank had 100 contacts, in ten rows of ten, arranged and numbered as below :—

101	102	103	104	105	106	107	108	109	100
191	192	193	194	195	196	197	198	199	190
181	182	183	184	185	186	187	188	189	180
171	172	173	174	175	176	177	178	179	170
161	162	163	164	165	166	167	168	169	160
151	152	153	154	155	156	157	158	159	150
141	142	143	144	145	146	147	148	149	140
131	132	133	134	135	136	137	138	139	130
121	122	123	124	125	126	127	128	129	120
111	112	113	114	115	116	117	118	119	110

In the bridging system, switches termed "selectors" and "connectors" were used.

Release was given by replacement of the receiver on the hook. Ringing was not automatic, but was performed by the calling subscriber, after having operated the dial, and a magneto generator was provided as part of the subscriber's equipment.

A central battery was employed to supply energy for the current impulses used to operate the switching mechanism; the negative side was connected to earth or to the common return recommended for small systems. For transmitting the impulses produced by manipulating the dial both the *a* and *b* wires of the line were utilised, the circuit being completed through earth, or common return. The "unit" impulses were transmitted over the *a* and the "tens" impulses over the *b* line.

In 1899 another Strowger exhibit was received in this country from Chicago, which embodied the principle of trunking and grouping, as now employed universally in all automatic systems, and which paved the way to automatic installations of unlimited capacity. The new system was introduced simultaneously into France and Germany, and telephone engineers generally began to contemplate the possibility of large unit automatic installations.

In America, the development of the Strowger system proceeded rapidly after the invention of the principle of trunking and grouping, and a number of installations of from three to six thousand lines capacity were manufactured in 1904–1906.

At the Exposition at the White City, London, in 1908, an example of the latest Strowger switching apparatus, embodying all the improvements incorporated in the Strowger system, as a result of the experience gained in actual operation under practical conditions in America, was exhibited.

The introduction of commercial machine telephone switching into this country was immediately preceded by a period in which the common battery system came to be regarded as the system *par excellence*. Apart from the displacement of local batteries accommodated at subscribers' premises by a common battery, centrally situated at the exchange, improvements accruing from the introduction of common battery systems which, in this country, invariably superseded magneto systems, were in the nature of the application of automatic devices for the purpose of reducing the work involved in the manipulation of a call by the subscriber, and

of the exchange operator. The improved operating facilities thus afforded had the effect of speeding up the operating generally, and of increasing the number of subscribers which might be allotted to one operator's answering position. Technically, the improvements secured in operating were the automatic call and clear given by the subscriber immediately on raising or replacing his receiver, as the case might be, the utilisation of the glowing of a lamp as signal which obviated manual effort on the part of the operator in restoring the indicator shutter, both in calling and in clearing, and the automatic dual supervisory signals, which, to a large extent, obviated the necessity for the operator breaking in with, or without, the inquiry, " Have you finished? "

As the common battery system was developed further automatic devices were added, for example, keyless or automatic ringing, which again reduced the operator's labour to the extent of depressing a ringing key. Thus the tendency was to eliminate gradually the manual element, by the adoption of automatic devices, and by so doing to increase the speed of operation and improve the service. By about 1906, the limitations of the common battery system began to be recognised, and it came to be appreciated that the system offered but little possibility of further improvement in the direction of reducing operating costs, and of effecting further saving in the time expended in establishing and clearing a connection.

During the time the common battery system was developing, and, in fact even for some time prior to its introduction, attention had been directed, chiefly in America, as shown, to the practicability of producing an exchange system of switching entirely by automatic means and completely eliminating the manual element. Consequently the question of machine switching began to be seriously considered in this country. The advances made in telephone switching by means of electro-mechanical devices in America were closely watched by British telephone engineers, but it was not until a practical measure of success was achieved that really serious attention was accorded the subject here.

The automatic system reached a practical and reliable form at a time not altogether auspicious for its trial in the United Kingdom. The National Telephone Company was working under a licence of definitely limited tenure under conditions which greatly restricted the amount of capital they were prepared to expend,

and which precluded the scrapping of plant possessing a life which extended beyond the date when their licence was due to expire. The Post Office started telephony in earnest in 1902 only, and its operations were for some time largely restricted to the Metropolis and to certain rural districts of the Provinces. It would have been ill-advised to embark on an immature venture of somewhat doubtful promise and financial stability. Machine switching plant was of an entirely different character from manual in regard to design, construction, and operation, and therefore, past experience with manual switching plant could not be utilised to any extent in estimating what its probable performance would be. Common battery plant, on the other hand, introduced into this country in 1900, was not so greatly dissimilar to the magneto and other switching systems which it displaced, and its probable behaviour could be more readily judged by past experience with pre-existing exchanges. Furthermore, although at that time the automatic system appeared to be capable of promising development, it was obviously far from perfect, and a cautious policy dictated the selection of the better known, and less risky, proposition.

It does not follow, as appears to be sometimes imagined, that because the automatic system has met with success in America it must necessarily be similarly successful in this country. The question of costs stands paramount, and costs in America cannot be directly compared with costs on this side of the Atlantic. One of the chief reasons why labour-saving devices of many descriptions are so largely adopted in America is that the cost of labour is high, and that the cost of machinery and mechanical appliances is relatively low. Consequently labour-saving devices which reduce, or even eliminate, the necessity for manual attention may be justified in America, where they are not in this country; such is actually true in various instances.

The chief questions which called for settlement in connection with the introduction of automatic exchanges in this country were :—

(1) Would automatic apparatus function properly and were the climatic conditions peculiar to these islands such as would permit of its successful operation?

(2) Would any improvement in service accrue from the adoption of machine switching?

(3) Would the British telephone-using public accept the automatic system and the additional manipulation of the dial it entailed, in preference to the manual, to which they were so well accustomed?

(4) Would the costs of automatic working compare favourably with those of manual?

(5) Were the additional costs (if any) of automatic working set off by the advantages (if any) which would accrue from its use?

It is obvious that none of these questions could be answered satisfactorily without practical trial, and consequently the British Post Office, about to assume control of the telephone services of the United Kingdom, adopted an experimental policy, in order to ascertain the relative merits of the several automatic systems which were developing, and to obtain experience and data to enable decision to be reached as to the future policy to be pursued.

It was not therefore until May 18th, 1912, that the first experiment in automatic telephony, and upon a section of the British public, was commenced, upon which date the first experimental automatic exchange to be installed in the United Kingdom was brought into service at Epsom, Surrey.

Epsom, which constitutes a portion of the outer London telephone area, was selected because of its relatively high percentage of local traffic, the suitable nature of its telephone users, and its near proximity to the headquarters of the Post Office Engineering Department in London, from whence the new venture might be kept under special observation.

The equipment was of the Strowger two wire type supplied and installed by the Automatic Telephone Manufacturing Company, Ltd., of Liverpool. It consisted essentially of five line-switch units each fitted with 100 line-switches, 80 first-selectors, 40 second-selectors, and 10 connectors. A complete description of the exchange was published in the *Post Office Electrical Engineers' Journal* for July 1912, by W. J. Bailey, followed in the same number by an account of the conversion to automatic working, and the operations associated with the transfer, by R. W. Callender.

On July 13th of the year in which the Epsom automatic exchange commenced to give service, a second automatic exchange, also of the Strowger type and supplied by the same company,

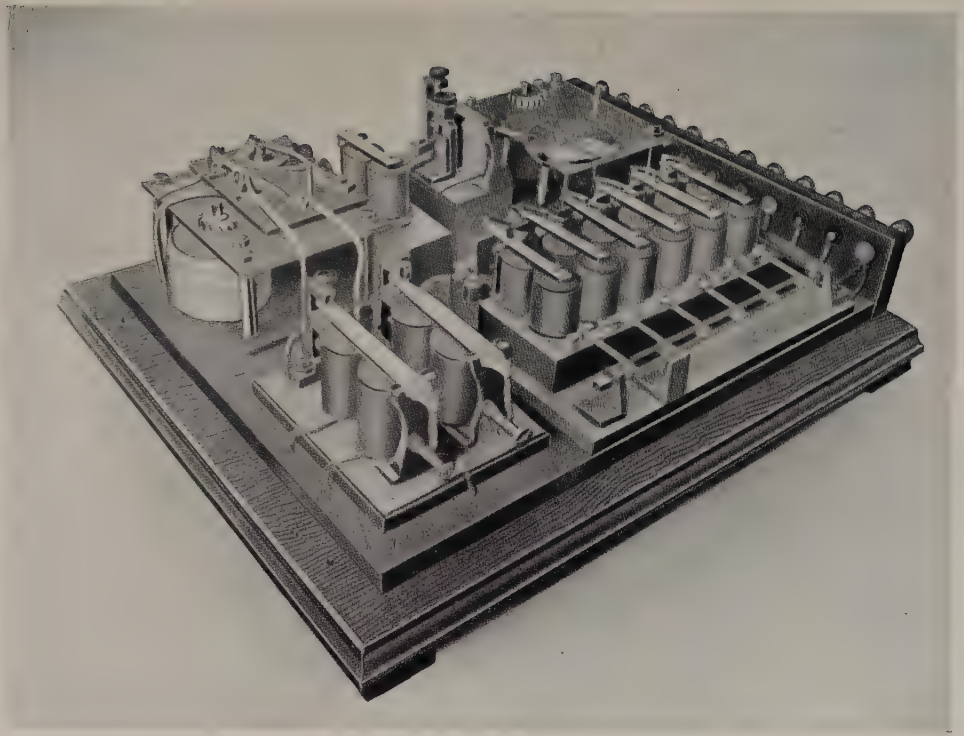

FIG. 174.—Dane Sinclair's Automatic Switching Device, 1883.

(From a block loaned by the Automatic Telephone Manufacturing Co.)

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FIG. 175.—One of the Automatic Telephone Manufacturing Company's Workshops, Milton Road, Edge Lane, Liverpool.

(From a photograph supplied by the Automatic Telephone Manufacturing Co.)

[*To face page* 539.

was opened for service at the General Post Office, London. This equipment was required to serve the officials of the Post Office as a private branch exchange and was known as " Official Switch." Its equipment was for 900 lines, with an ultimate capacity of 1500, and it enabled the engineers of the Post Office, not only to keep under close observation its technical performance, but also by its use every day to gain actual experience of its working, in order to enable them to judge the merits of the system.

The Automatic Telephone Manufacturing Company, Ltd., of Milton Road, Edge Lane, Liverpool, the first firm to undertake the manufacture of automatic telephone equipment in this country, was formed in November 1911, and acquired the Strowger patent rights, for the United Kingdom, of the Automatic Electric Company of Chicago, the proprietors of the Strowger patents; the manufacturing experience of that firm was also available to them. The telephone and telegraph factory of the British Insulated and Helsby Cables, Ltd., situated at Liverpool, was acquired, and directors of the board of the Helsby company joined the board of the new company. The first chairman was Mr. James Taylor, the office now being filled by Sir Alexander Roger. The managing director was Mr. Dane Sinclair, previously of the British Insulated and Helsby Cables, Ltd., and formerly engineer-in-chief to the National Telephone Company. The two companies are quite independent, but have a reciprocal working arrangement. It was thus left to private enterprise to arrange the necessary manufacturing facilities in this country, and to secure the Strowger patents. £300,000 was spent in this exploitation.

The Continental patent rights for Strowger Automatic equipment are in the hands of Messrs. (French) Thomson Houston Company, Paris, and Messrs. Siemens and Halske, Berlin, who manufacture this equipment for the territory allotted to them.

The Automatic Telephone Manufacturing Company's factory at Liverpool is capable of manufacturing automatic switching plant at the average rate of 1500 lines per week. A photograph of one of the company's fine workshops is reproduced in Fig. 175, and a portion of a Strowger Automatic Exchange is illustrated in in Figs 176 and 177. For these photographs, and also for much of the information contained in this chapter relative to Strowger apparatus, the author is indebted to Mr. H. H. Harrison, of the Automatic Telephone Manufacturing Company.

The first automatic equipment for a public telephone exchange, manufactured at the Liverpool works, was that for Newport, opened for service on August 14th, 1915.

In addition to their activities in the manufacture of automatic equipment for large public exchanges, the Automatic Telephone Manufacturing Company have laid themselves out to provide for private users in the form of private automatic exchanges of from five lines and upwards. Advertised special features of the company's P.A.X. system are (*a*) the conference line, whereby a number of stations may be automatically connected together for conference purposes, (*b*) the code call, by which an absent official, within call, may be informed that his attention is desired, (*c*) watchman's service, (*d*) interception of conversation by a favoured party, and (*e*) fire and emergency service.

Below is given a summary of installations supplied by the Automatic Telephone Manufacturing Company, and manufactured at their Liverpool factory, up to October 1922 :—

Country.	Lines fitted.		Lines under construction.	
	M.A.X.	P.A.X.	M.A.X.	P.A.X.
British Isles.	22,590	4,058	10,580	1,435
Mesopotamia.	1,000	—	—	—
India.	3,700	25	11,300	—
South America.	17,300	165	—	—
South Africa.	—	80	—	—
China.	8,000	588	200	50
Japan.	—	205	—	—
Straits Settlements.	—	40	—	—

Although the Strowger Automatic Telephone System was invented and has been highly developed in the United States, a number of British engineers have taken part in its improvement in this country, amongst whom the following inventors may be mentioned :—

Messrs. W. Aitken, P. Bates, W. R. Carter, Collyer, C. Gillings, R. Mercer, G. W. Moore, A V. Newell, A. J. Ray, J. Savin, S. R. Smith, and P. Webster.

An admirable publication by R. Mordin, entitled the " Strowger Automatic Telephone Exchange," fully describes Strowger

FIG. 176.—Portion of a Strowger Automatic Exchange.

(From a photograph supplied by the Automatic Telephone Manufacturing Co.)

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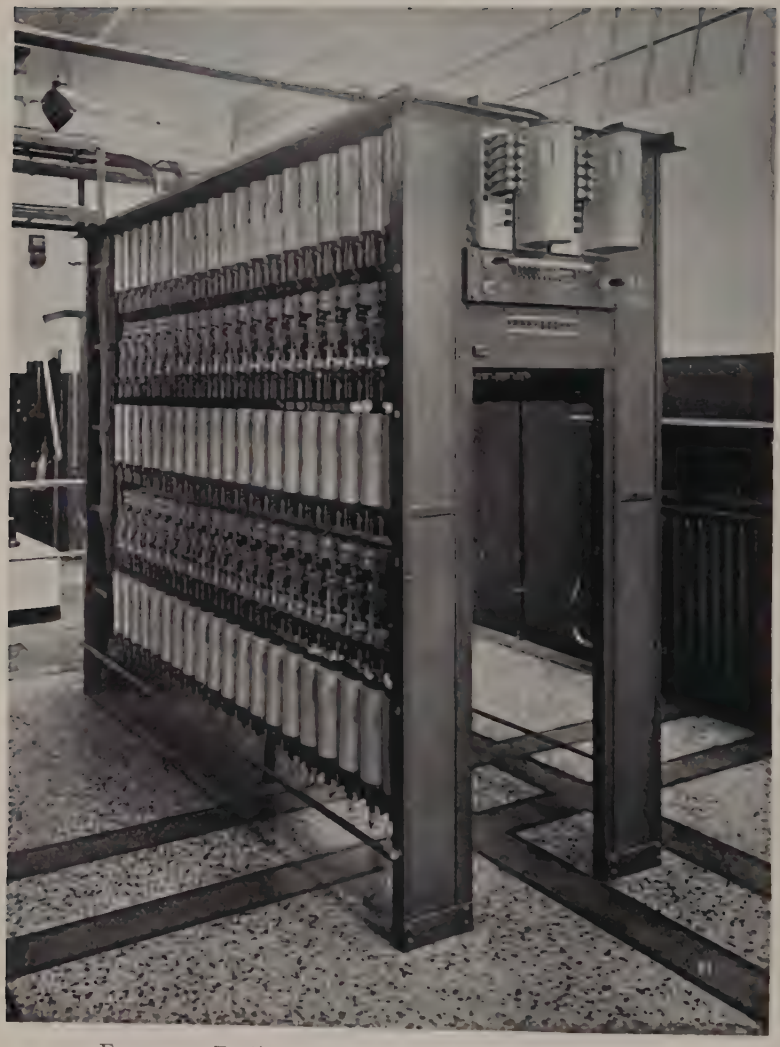

FIG. 177.—Portion of a Strowger Automatic Exchange.
(From a photograph supplied by the Automatic Telephone Manufacturing Co.)

[*To face page* 541.

automatic practice as employed by the British Post Office in this country. As the Strowger system has received fairly liberal literary attention, and has been adequately treated in numerous publications of comparatively modern date, detailed description is unnecessary.

The equipment details and circuit arrangements of the Epsom and Official Switch Exchanges followed American standard practice, and after all due consideration the opinion was arrived at that the American system did not in every way satisfy British requirements. Consequently, engineers of the Automatic Telephone Manufacturing Company, and of the British Post Office, collaborated in modifying and developing the system so as to accord with British practice in the handling of traffic and in engineering arrangements. The developments which transpired are described in an article, contributed to the *Post Office Electrical Engineers' Journal* for July 1915, by J. Hedley, entitled "Developments in the Strowger Automatic System."

In Table 20 particulars of the exchanges fitted with Strowger apparatus, manufactured and installed by the Automatic Telephone Manufacturing Company, since the two exchanges Epsom and Official Switch were opened, are included, and it will be seen that of the total of 23 automatic exchanges which now exist for the public service in this country, 12 are of the Strowger type, equipped by the firm mentioned. The largest of these is that at Leeds, formally opened for public service at 2.0 p.m. on Saturday, May 18th 1918, by His Majesty's Postmaster-General, the Right Hon. A. H. (now Lord) Illingworth, M.P. Sir William Slingo, Engineer-in-Chief, and other Post Office officials, and representatives of the commercial community of Leeds and of the Press were also present. This exchange, the largest of its kind in Europe, was equipped for 6600 lines with an ultimate capacity of 15,000. It is the first exchange in this country in which the calling subscriber is required to dial as many as five digits.

As is now customary, even in large and involved operations of this class, the transfer of subscribers' lines from the old manual to the new automatic equipment was accomplished practically instantaneously, and within a few seconds of the formal operation of changing over the first subscriber's line, performed by the Postmaster-General, the huge remainder was severed from the old and connected to the new equipment.

The whole of the plant comprising the exchange, excepting batteries and meters, is accommodated on the uppermost floor of a building specially designed and constructed for the purpose in Basinghall Street. All local traffic in Leeds, except that originating at call offices, is dealt with automatically, including the calls from most of the outlying exchanges in the area, which are dialled direct over the 144 junction lines which exist for the purpose.

For a description of the Leeds automatic equipment, reference should be made to an article, "Leeds Automatic Exchange," by E. S. Francis, published in the *Post Office Electrical Engineers' Journal* for October 1918.

The Lorimer Automatic System

Two years transpired before the third automatic exchange to be provided by the Post Office was brought into service at Hereford on August 1st, 1914. This equipment was of an entirely different type from that installed at Epsom and the General Post Office; it was known as the Lorimer system, and was manufactured by the Canadian Machine Telephone Company of Toronto, Canada.

A characteristic of the Lorimer system is the cylindrical switches over the contacts of which the "wipers," forming part of the selecting device, travel in one direction only.

As in the Western Electric Company's system, shortly to receive mention, the switches are power driven; they are propelled by a constantly revolving shaft, by means of a mechanical clutch, comprised of toothed wheels, brought into operation by means of an electro-magnet.

The subscribers' calling device was one in which, like the form originally adopted by the Betulander Company in their automatic system, to be referred to later, the number to be called is set up by the adjustment of certain levers, and can be seen by the subscriber in plain figures in front of him, before turning a crank and lifting the receiver in order to set the calling mechanism in motion. Advocates of this method of calling claim for it that there is less liability to error by the calling subscriber, and that he may check the number he desires to call before setting the machinery in operation, or even afterwards if a wrong number is obtained.

Hereford is the only exchange of the Lorimer type installed in

this country. The equipment was fully described and illustrated in an article in the *Post Office Electrical Engineers' Journal* for July 1913, by W. J. Bailey, under the title, "The Lorimer Automatic Exchange at Hereford."

The Western Electric Company's Rotary Automatic Telephone System

Electro-mechanical switches, self-propelled and required to operate in direct response to the impulses imparted by manipulation of the subscriber's dial, must necessarily be of light construction. To secure stability of electrical contact in moving gear, it is desirable that the actual contact should be made reliable by the application of a certain amount of mechanical pressure between the contact points or faces, and that the contact pieces themselves should be of reasonably substantial construction. The desirability of securing firm and reliable contact between the essential moving parts of an electro-mechanical telephone switching system led to consideration being given by inventors to the possibility of providing means whereby the switches might be actuated by power, entirely independent of, but nevertheless controlled by, the impulses transmitted from the subscriber's dial. Furthermore, since in any switching system there is necessity for providing several channels for the maintenance of simultaneous conversations, the provision of multiple switches is necessary, and the problem as to whether, from the point of view of first cost and annual charges, it was more economical to employ comparatively few switches, with banks of numerous contacts, or many switches having small banks, had to be faced by manufacturers.

Study of the characteristics of manual switching in large and small exchanges revealed that traffic in a telephone system is not, as it were, haphazard, but follows a more or less regular course or order and may be predetermined with a fair degree of accuracy by application of the mathematical theory of probability. The theory of probability, in so far as its adaptability to machine telephone switching is concerned, has been discussed at length by numerous writers, and at the conclusion of an article by G. F. O'dell in the *Post Office Electrical Engineers' Journal* for October 1920, entitled "Theoretical Principles of the Traffic Capacity of Automatic Switches," is given a list of the principal contributions

on the subject, and references to tables of assistance in dealing with the calculations involved. It has been shown that the probable number of simultaneous conversations occurring in a large group of lines is less in proportion than that for a small group of lines. It therefore followed that the larger the number of lines which can be made available to one switch, the fewer such switches will be required. Illustrative of this point, in a group of, say, 200 lines, the probable number of simultaneous conversations will be approximately 16. If the 200 lines be regarded as two separate groups of 100 lines each, then the probable number of simultaneous conversations in either group will be about 10. To manipulate the traffic of 200 lines with 200-line switches it will be necessary therefore to employ 16 switches and 3200 terminals; with 100-line switches 20 switches will be required, but only 2000 terminals. Therefore if the saving effected in switches, namely, 4, more than counterbalances the cost of the additional 1200 terminals, it is more economical to employ 200-line switches. It is also necessary to take into account that the cost of upkeep of a switch, by which is meant a rotating set of wipers or brushes, is greater than the cost of upkeep of a stationary bank of contacts.

As an outcome of the foregoing considerations, the Western Electric Rotary System was developed and placed upon the market. This system is essentially different in its characteristics, and in operation, from systems which preceded it, and an understanding of its principles involves independent study. There have been several descriptions published of the construction and operation of this ingenious, though necessarily somewhat complex, system, and it is not proposed to describe it in detail. Reference may be made to the following publications for illustrated descriptions of the system :—

1. Paper read before the London Centre of the Institution of Post Office Electrical Engineers on December 4th, 1916, entitled "The Western Electric Company's Automatic Telephone System," by B. O. Anson.

2. Article in the *Post Office Electrical Engineers' Journal* for July 1914, entitled "Darlington Automatic Exchange," by J. Hedley.

3. Article in the *Post Office Electrical Engineers' Journal* for January 1917, entitled "Dudley Automatic Exchange," by H. W. Dipple.

The methods of selection most generally employed have naturally followed the decimal notation, and therefore switches have not accommodated more than 100 lines. The subscriber's dial commonly used is arranged with ten holes, and a complete revolution of the finger wheel will cause ten impulses to be transmitted; successive operations of the dial will transmit successive groups of impulses ranging from one to nine. In other words, those impulses are arranged on a decimal basis. In using banks containing more than 100 contacts, the decimal notation followed by the originating impulses of the dial obviously cannot be retained throughout the system, and it becomes necessary therefore to provide means for translating the dial impulses into a system of impulses suited to whatever arrangement of the terminal banks be decided upon. This function, in the Western Electric Rotary System, is fulfilled by a device termed a " register," which is, as it were, the brain of the system. This method of operation is known as the " reverse impulse control "; it is an outstanding feature of this machine switching system, and is distinguished from systems in which the selecting mechanisms are controlled directly by the calling device at the subscriber's station.

Further functions of the register are :—

(1) To receive the impulses from the calling subscriber's dial.

(2) To send out impulses, translated in accordance with the arrangement of the terminal banks, when the switches are ready to receive them. This enables hunting to take place over large groups of junctions, thereby economising in the number of junctions required to carry a given traffic.

(3) To check off the revertive impulses from the switches and assist in the exact placing of the brushes.

(4) To delay, if necessary, the sending of impulses until a free switch be available, so that no calls be lost due to traffic congestion.

The " sequence switch," another feature peculiar to the Western Electric Company's system, was developed to perform important functions in establishing requisite circuit conditions and, at the same time, to effect economy in relays. This device may be regarded as a mechanical relay, or be likened to an electric sign flasher; by its means certain relays are made to serve similar functions in different successive circuits; no current is required to maintain the sequence switch in any one of its stationary positions.

The "Line Finder" is the first switch to operate on a call being made and fulfils the function of finding the calling line, and connecting it with a disengaged register. Each line finder accommodates 60 subscribers' lines, and has 20 horizontal and 12 vertical terminals, 240 contacts in all; 4 vertical and adjacent terminals are utilised for each subscriber's line.

The final selectors (or connectors) each accommodate 200 lines. There are 20 contacts in each of the ten levels of the bank.

The Group Selectors (analogous to second selectors) are precisely similar in construction to the final selectors, but each has 22 horizontal and 30 vertical contacts in the bank, 660 in all for 220 circuits.

The action of all the switches is rotary, and they are all power driven. The power is derived from electric motors, coupled to a system of shafting and counter-shafting connected by bevel gear. Situated immediately beneath the groups of switches, and driven from the counter shafting, are a series of horizontal spindles from which power is applied to the various switches in a novel and interesting manner, by means of magnetic clutches.

The first full automatic exchange of the Western Electric Company's rotary type to be brought into public service was that of Darlington, opened on October 10th, 1914. This exchange was very fully described and illustrated in an article by J. Hedley in the *Post Office Electrical Engineers' Journal* for July 1914. A second exchange of the same type, but in which certain improvements and modifications of the equipment were introduced, was opened at Dudley on September 9th, 1916, with 316 subscribers' lines, and is described in an article by Mr. H. W. Dipple, in the *Post Office Electrical Engineers' Journal* for January 1917. Two photographs of the Darlington equipment are reproduced in Figs. 178 and 179.

Siemens System

The well-known firm of Siemens Bros. and Co., of Woolwich, commenced the manufacture and development in this country of telephone machine switching appliances in 1912.

The Siemens system is not very greatly dissimilar from the Strowger system in many respects, but differs from it essentially in the form of line switch employed and in the fact that the connectors have no side switch, but are controlled entirely by relays.

FIG. 178.—Darlington Automatic Exchange Western Electric Company's Rotary System. Registers and Final Selectors.

(From a photograph by the author.)

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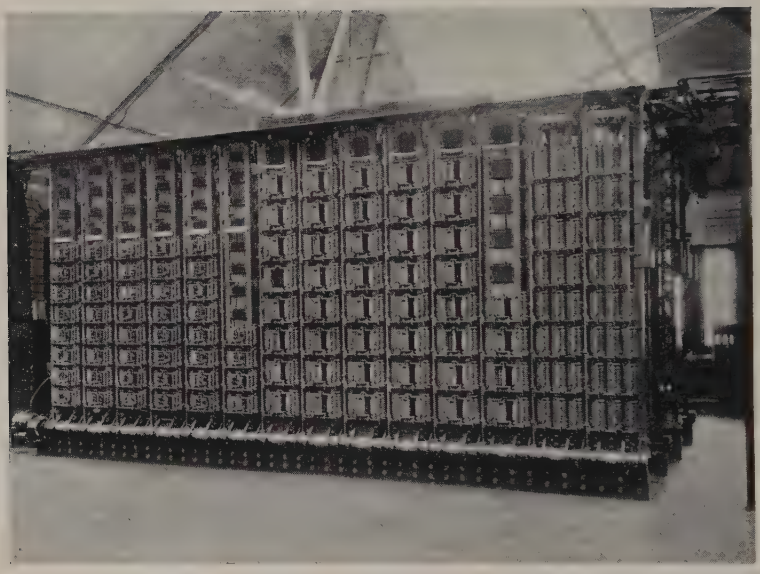


FIG. 179.—Darlington Automatic Exchange, Western Electric Company's Rotary System. Line Finders, Group Selectors and Sequence Switches.

(From a photograph by the author.)

[*To face page* 547.

The characteristic feature of the system is the " Preselector," the outcome of a good deal of development work commenced as early as 1901. The preselector is a rotary line switch; one is provided for each subscriber's line, as in the case of the line switch of the Strowger system, and its function is the same, *i.e.*, to find a disengaged trunk to a selector. The switch rotates in one direction only, its movement being derived from a ratchet wheel actuated by the armature of a driving magnet. The Siemens selector has three banks of contacts; the uppermost is the private bank.

The first exchange equipped and fitted by Messrs. Siemens Brothers and Company for the public telephone service in this country was the exchange at Grimsby, brought into operation on September 14th, 1918. For particulars of this exchange reference should be made to an illustrated article, by F. McMorrough, in the *Post Office Electrical Engineers' Journal* for July 1916, entitled " Grimsby Automatic Exchange."

Grimsby was followed by another and similar exchange at Stockport, opened for service on August 23rd, 1919. It was equipped for 950 lines; the lines were arranged in 14 groups, each having access to 10 second preselectors. The 140 second preselectors were given access to 70 first selectors, and 80 first selectors were provided for traffic incoming from the manual board. The exchange was described in an article in the *Post Office Electrical Engineers' Journal* for January 1920, by A. B. Eason, M.A.

Southampton automatic exchange, also equipped by Messrs. Siemens for the Post Office, was opened on June 30th, 1923.

Associated with the provision of telephone service in remote country villages are problems peculiar to the circumstances under which such exchanges must necessarily be worked and which do not occur in the case of exchanges situated in larger and more densely populated places. The automatic system possesses many attractive features to commend it for service in rural districts where the telephone requirements are of small order, and manufacturers of automatic telephone apparatus have devoted attention to the production of small automatic equipments specially suited to the requirements of such cases. Incidentally much attention has also been bestowed upon the production of private automatic exchanges, either to work in association with or entirely apart from the public telephone system, as may be desired, and private

automatic telephone exchange apparatus of various types and manufacture is now available.

In country districts, the chief difficulties with which the telephone administration has to contend are those associated with the provision of adequate accommodation for the equipment and suitable attendance for its operation. So far as the latter feature is concerned, it is not reasonable to count upon the same expert and prompt attention at a country village exchange with a small number of rural lines operated on the manual system, as may rightly be expected at a larger exchange, where unremitting attention at the switchboard is justified by the traffic; at very small exchanges the attendance of an operator whose whole time is devoted to operating cannot usually be arranged for economically. The satisfactory disposal of night calls at small rural exchanges is a further difficulty.

In village automatic exchanges these difficulties disappear, inasmuch as the apparatus is always available for service, without the attention of an operator and renders equal service by night and day; nevertheless the employment of automatic switching apparatus for rural telephone service possesses disadvantages and creates difficulties absent in manual working.

The electrical energy required for an automatic exchange is generally greater than for manual; if primary cells be used, their upkeep is costly, and frequent attention is necessary; it is therefore highly desirable that secondary cells should be employed, but nevertheless their charging and maintenance generally necessitate frequent skilled attendance. Furthermore, electrical power for charging secondary cells is not usually available in country villages and if secondary cells be used recourse must therefore be had to some prime source of energy, such as a gas or petrol engine, which again needs frequent skilled attention. Attempts have been made with limited success to charge cells from the main exchange over the junction line, or lines, when not in use, but the practical difficulties have not yet been fully surmounted. The reporting of and testing for faults, and the working of prepayment stations, also present difficulty; there are also a number of other minor considerations which render the institution of village automatic telephone service a matter of some complexity.

Messrs. Siemens' engineers have devoted much attention to the

particular requirements of automatic service in small villages and evolved a system which, it is claimed, largely fulfils the requirements of the British Post Office.

The first village automatic exchange to be brought into service in this country was supplied by Messrs. Siemens for the small market town of Ramsey, Huntingdonshire, with a population of about 5000. The equipped capacity of the exchange was for 40 lines, and it commenced to give service on October 24th, 1921.

In addition to the three aforementioned public exchanges Messrs. Siemens have equipped a large number of private automatic exchanges in this country, ranging in size from 25 to 200 lines.

Particulars of the public exchanges equipped and in hand by Messrs. Siemens are given in Tables 20 and 21.

The Relay Automatic System

In a somewhat remote corner of the London Electrical Exhibition of 1911 there was included amongst the novel exhibits a small case containing a device described as the Betulander System of telephone switching. It excited considerable interest amongst members of the telephone profession at the time, and comprised a series of ten switches or selectors, one for each of the ten lines accommodated; two telephone instruments were connected for purposes of demonstration.

The groups of contacts by which selection of any particular line was made were arranged above and behind the selector switches, and consisted of a series of metal projections mounted in a block of insulating material. The small size and light weight of the switches were prominent features of the device. The switches were self-starting and moved in one direction only. The contrivance was representative of an electro-mechanical telephone switching system devised by Gotthief Angarius Betulander, an engineer in the Swedish Post Office, who had been studying and working upon the problem of automatic telephone switching since about 1900. Some small exchanges were installed in a number of towns in Sweden, and it is believed that one of the small exchanges opened as far back as 1903 is still giving service. In about 1911 the Betulander system was exploited in France by the "Société des Téléphones Automatiques, System Betulander," of 38 Rue Le Peletier, Paris, and amongst other early installations may be mentioned the network for the Prefecture

of the Seine in the Bois de Boulogne, Paris, still in use for police and ambulance purposes.

In January 1913, Marconi's Wireless Telegraph Co., Ltd., acquired world wide control (excepting Sweden) of the Betulander Patents, and in August 1913 formed the Betulander Automatic Telephone Co., Ltd. A demonstration exchange was fitted up at Marconi House, and the system was advertised and some business done.

Betulander's early work was confined to electro-mechanical switching devices and in the search after a means for effecting economy in the number of switches required in electro-mechanical systems, in conjunction with Nils Gunner Palmgren he invented a new trunking principle which made possible the use of relays for automatic switching. Prior to this invention, the number of relays necessary for an "all relay" exchange would have been prohibitive.

The first models of the relay system were received in this country only two or three months before the outbreak of war, and the firm's activities being diverted to war purposes, with the exception of two or three small switchboards for private use, the development of the system was practically suspended until after the Armistice of November 1918.

Early in 1915, the name of the Betulander Automatic Telephone Company was changed to the Relay Automatic Telephone Co., Ltd., and under the directorship of Mr. C. B. Clay, late Metropolitan superintendent for the National Telephone Company, the development of the relay system was taken in hand in earnest. The technical development of the system in this country has been in the hands of Messrs. F. Morley Ward and G. H. Bryant, both late of the National Telephone Company.

In the original Betulander system an electro-mechanical selector was employed, moving in one direction only. The relay system, which replaced it, was not even a modification of its inventor's original system, but was an entirely new departure depending upon a different and novel principle. As its name implies, the system is dependent upon relays for performing the necessary switching function, and upon relays alone. This is its characteristic and novel feature, and it is the first and up to the present time the only system of its kind. The whole of the requisite operations of number selection, connection, ringing and

disconnection, with their auxiliary functions, are performed entirely by means of relays of the ordinary telephone type. There is thus no frictional wear of any kind, and it is claimed that the absence of moving parts reduces to a minimum the liability to derangement due to wear and tear. The only moving parts in the switching system proper, are the relay armatures, which move through a distance of but one thirty-second of an inch and with negligible inertia. Electro-mechanical devices involving searching of a brush or wiper over a number of contacts, and the accompanying rotary and longitudinal movement, are entirely eliminated in the relay system.

The universal adoption of the electro-magnetic relay for practical telephone switching purposes dates back to the introduction of the Common Battery Relay Switchboard by the Western Electric Company in 1900; since that time, when the employment of relays in telephone circuits was regarded by many with no little scepticism, relays have been in constant and extensive use and their performance has been under the closest surveillance; the verdict has long been that absolute reliance may be placed upon them to perform their functions with unfailing precision and regularity.

The relays employed in the Relay Company's system are similar in construction to those employed for many years in connection with manual switching systems; the majority have six springs; the largest has as many as 36 springs with contact points making 18 contacts, but it is found that after the initial adjustment, carefully performed at the factory before issue, they seldom require further attention. A feature of these relays is the employment of a thin non-magnetic metal strip, varying in thickness according to the particular functions which the relay performs, to prevent the armature sticking to the core, instead of the customary brass stud or screw. The relay system also differs essentially from other systems in that each subscriber's line terminates at one place on the equipment only, and is not repeated or multipled in front of a series of selectors or connectors; both incoming and outgoing calls are completed respectively over incoming and outgoing trunks, through the contacts of the same small group of adjacent relays.

To build up a connection on a 100 line, or larger, system, the trunks or junctions joining up the different groups are connected

by means of what are termed "links," which fulfil the same function as a cord on a manual system. The first or primary link takes the place of the line switch, or preselector, employed in other systems, and acts in a similar manner, automatically to extend the calling line to the first junction, when the receiver is lifted. The following links connect trunk to trunk, and finally the last trunk to the subscriber wanted, in accordance with the digit impulses.

The proprietors claim for their system that it includes the advantages of all other systems with the disadvantages of none, and that it is entirely free from detrimental results due to :—

(*a*) The use of electro-mechanical switches and other cumbersome mechanical devices which require considerable attention in regard to adjustments, oiling and cleaning;

(*b*) the liability to be adversely affected by varying climatic conditions, including the result of dust, heat, damp, etc.

The relay system is described, without entering into complex technical matters, in the several publications issued by its proprietors, and with more detail and reference to its working parts and their arrangement, in an article contributed by Mr. A. B. Eason to the *Post Office Electrical Engineers' Journal* for April 1920.

A large number of private automatic exchanges of the Relay type have been installed, all of which have given satisfactory results. Several public exchanges are in hand for India, a number of which have already been shipped. A number of private automatic exchanges are arranged for connection to the public telephone service, including the Government Houses of Alipore, Poona and Bombay in India, and the India Stores Depot, *Liverpool Courier* and *Evening Express* Offices, the North Eastern Marine Engineering Co., Ltd., and others in this country.

The Swedish Post Office had a trial semi-automatic exchange in use for some years as part of the Stockholm network, and this has now been dismantled for removal to a smaller town as a full automatic exchange. It is understood that a 3000 line exchange for Sundsvall is now under consideration.

The first Relay automatic exchange for the public telephone service in this country was that provided by the Relay Automatic Company for the British Post Office at Fleetwood, opened for service on July 15th, 1922.

The equipment was described and illustrated in *The Electrician*

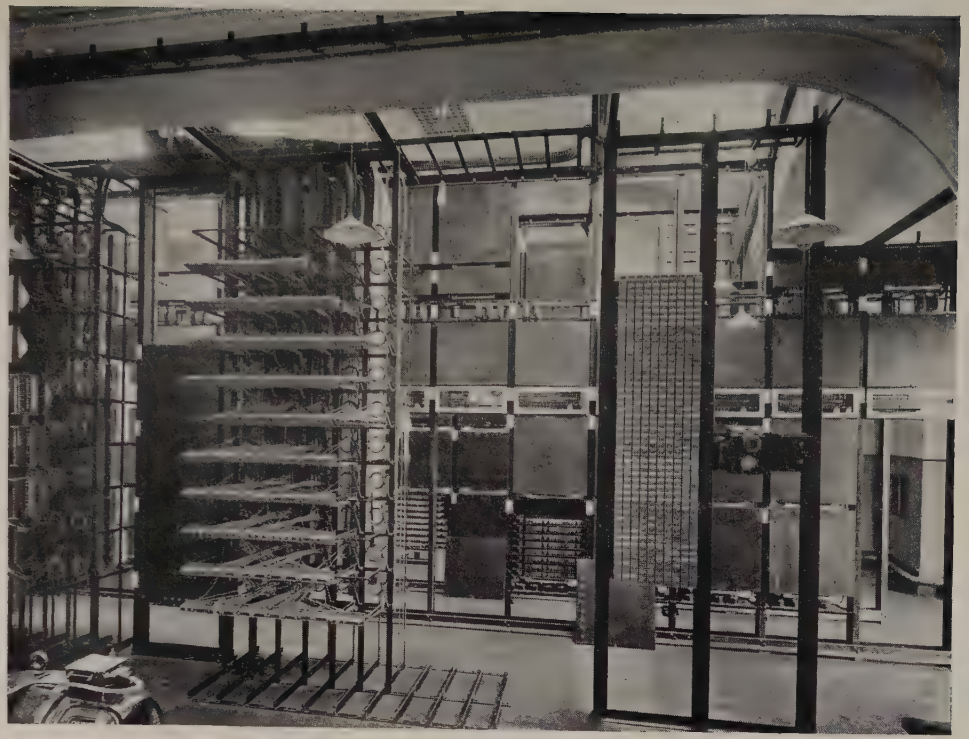


FIG. 180.—Fleetwood Automatic Exchange, Relay Automatic Telephone Company's System.

(From a photograph supplied by the Relay Automatic Telephone Company.)

[*To face page* 552.

FIG. 181.—Fleetwood Automatic Exchange, Relay Automatic Telephone Company's System.

(From a photograph supplied by the Relay Automatic Telephone Company.)

[*To face page* 553.

for November 3rd, 1922, in *The Electrical Review* and also in *Engineering* for September 29th, October 6th, and October 13th, 1922.

On December 8th, 1923, a private branch automatic telephone exchange, manufactured and installed on behalf of the Post office by the Relay Automatic Telephone Company, was brought into service at Messrs. Debenham's, 17 Wigmore Street, London. This private automatic exchange has an initial equipment of 400 and an ultimate capacity of 1270 lines, and is the largest private automatic exchange existing in the British Empire.

The Relay Automatic Telephone Company has also erected at the British Empire Exhibition at Wembley, a 200 line Relay private automatic exchange. This exchange provides the internal telephone service for the Exhibition administration as well as serving as an exhibit by the Relay Company. Its installation was completed in December 1923.

The Western Electric Company's Panel Automatic System

The switches employed in the Western Electric Company's rotary system were as large in capacity as was economical, and considered desirable with the rotary form of switch, but in a later system produced by the same company, in which the banks of terminals or contacts are arranged in one flat vertical plane, the use of switches of still larger capacity is made possible. This system, known as the panel system, from the fact that the contact banks are arranged as flat panels, is similar in general principle to the rotary; the essential difference is that selection is effected, not by means of a rotary power-driven switch, but by means of brushes supported on vertical rods, moving vertically, and placed on either side of a double contact bank, in order to effect economy in floor space and in banks.

The evolution of the panel system was the direct result of systematic attempts deliberately made to provide satisfactorily for the complex telephone traffic requirements of large and densely telephoned multi-office areas, where a number of large exchanges are required, and consequently where the proportion of inter-exchange traffic is large, a condition which perhaps applies to the larger American cities more than to any city in this country excepting the Metropolis.

The multiple bank consists of a large number of brass strips,

insulated from each other, and assembled to form 300 contacts for 100 lines as line finders, and for 500 lines capacity in other switches. The strips are provided with projecting lugs on either side, to serve as contact points, across which the vertically moving brushes travel. Five of these banks, or panels, are mounted one above another, to form the complete bank for one selector frame.

The triple contact brushes are carried upon vertical elevator rods, of which there are 30 on each side of the panel.

Mechanical up and down drives, at two speeds, consisting of friction rollers situated at the base of the frame, are arranged so as to grip the elevator rods at their lower extremities by means of electro-magnets, and to elevate the brushes quickly to, or to restore them quickly from, the required group of terminals, selection of the particular contacts being accomplished at the slower speed with accuracy.

The line finders may be either of the panel type, as briefly described, or of the type employed in the Western Electric Company's rotary system.

Sequence switches play an important part in the panel system as in the rotary, and registers are also employed, although they take an entirely different form and are known as " senders."

The sender is a marvel of ingenuity, as may be gathered from examination of the following list of some of the functions which it performs :—

1. Receives the impulses of the subscriber's dial on a decimal basis, converts them to a non-decimal basis, and in that form retransmits them to the particular group of circuits involved in the connection.

2. Accepts the transmitted impulses as rapidly as they may be sent, but retransmits them in such a manner that each mechanism receives them at the uniform rate for which it was specifically designed.

3. Permits of inter-exchange communications by employment of code letters, signifying exchanges dialled prior to number.

4. Translates the exchange code dialled into impulses such that trunks to the required exchange are selected.

5. Differentiates between calls for automatic and manual exchanges, and controls selection according to the arrangements at the incoming end.

6 Controls call office lines with automatic boxes and prevents conversation ensuing before coin is inserted. Shunts line to monitor in case of undue delay, or other abnormal circumstance, and returns coin to calling subscriber should call be ineffective.

7. If the communication with certain exchanges involves excess payment, call is shunted to monitor, if subscriber dials a subscriber connected with any such exchange.

The Panel System has not yet been introduced into this country, but nevertheless the above brief particulars of this ingenious system may not be without interest.

Coventry Automatic Telephone System

In Chapter XV. mention is made of the organisation known as the Peel-Conner Telephone Works, formed under the proprietorship of the General Electric Company, for the manufacture in this country of telephone apparatus and exchange plant. At the outset attention was confined to the manufacture of manual equipment, but the success achieved by the firm, and the important advances made in machine switching, generally led Mr. H. Hirst, chairman of the General Electric Company, and Mr. M. S. Conner, director of Peel-Conner Telephone Works, to give consideration to the production of automatic equipment.

The occasion of the removal of the Peel-Conner Telephone Works from Manchester to Coventry was regarded as a suitable opportunity to embark upon the proposed venture, and, as a result of the consideration given to the matter, on April 23rd, 1920, "Coventry Automatic Telephones, Ltd.," was incorporated, in order to provide a separate organization for the manufacture in this country of automatic equipment. At this time the patent situation relative to machine switching was somewhat complex, there being in existence three large independent patent groups, namely, the Western Electric Company, the German Group (Siemens and Halske with its associated companies), and the North Electric Manufacturing Company of Galion, Ohio, U.S.A. The last named company hitherto had not entered practically into the automatic telephone business in this country, but owned some of the fundamental key patents in automatic telephony and included amongst its leading officials such eminent telephone engineers as Mr. Frank R. McBerty, the inventor of the Western Electric

Company's rotary system, Mr. Kempster B. Miller, Mr. Samuel G. McMeen and Mr. Charles North, a successful designer of automatic switches.

Negotiations were therefore conducted with the North Electric Manufacturing Company which culminated in the acquisition by the Coventry Automatic Telephones, Ltd., of the rights to manufacture automatic switching equipment under the North Electric Manufacturing Company's patents in this country, and arrangements were made for intimate co-operation between the two concerns.

A considerable amount of inventive and constructive work had to be performed before the newly-formed Coventry Company was in a position to undertake the large orders which it anticipated from the British Post Office and other authorities, but eventually, largely due, it is understood, to the combined efforts of Mr. McBerty and Mr. A. R. Kahl, chief engineer of the Peel-Conner Telephone Works, and their respective staffs, the difficulties in the way of designing an efficient and reliable automatic telephone system were ultimately surmounted.

Coventry Automatic Telephones, Ltd., is now, or it is expected will be in the very near future, in a position to manufacture and instal automatic telephone equipment of several descriptions as follows :—

(*a*) Auto-manual equipment of any size based upon the circuit arrangements, general design and construction of the equipments produced by the North Electric Manufacturing Company during the past fifteen years, and installed in several large exchanges in America.

(*b*) Full automatic machine switching systems, employing as selectors and connectors 100 point machine switches, similar to the Strowger, but of a type devised by the North Electric Manufacturing Company, in combination with either all-relay line finders, or individual line preselectors.

(*c*) All-relay full automatic systems as already supplied to the India office for twelve exchanges.

As mentioned, the selectors and connector switches of the Coventry Automatic Company's system take a form similar to that of the Strowger. Each such switch accommodates 110 lines with ten horizontal and eleven vertical rows of contacts. Unlike the Strowger switch, the vertical movement follows the rotary one,

and therefore the bank contacts are arranged edgewise instead of flatwise.

A brief description of the Coventry Automatic System appears in Vol. I of Aitken's "Automatic Telephone Systems."

In May 1922 the Board of the General Electric Company offered Sir William Noble, Engineer-in-Chief to the Post Office, upon his retirement from that office, a seat on the board of directors and the position of managing director of the Telephone Works, which he accepted.

The system of automatic switching developed by the Coventry Automatic Telephones, Ltd., has now been adopted in practice for telephone exchanges associated with the public telephone system of this country at Dundee and Broughty Ferry, both being brought into service simultaneously on March 15th, 1924.

Mr. V. Amberg, of the Peel-Conner Telephone Works, has kindly supplied information relative to the machine switching system of the Coventry Automatic Telephones, Ltd.

Table 20 gives particulars of all the automatic exchanges brought into service by the British Post Office in connection with the public telephone system of this country up to April 1924.

The relative advantages and disadvantages of the manual and automatic systems and the economics of the question have frequently been discussed. There was at one time in this country a good deal of scepticism as to the merits of the automatic system, but one by one the technical objections urged against it have been swept away by the fact that automatic exchanges of the several reliable types available have, as shown in previous pages of this chapter, been brought into practical operation in this country, and have demonstrated their ability to render service now very generally accepted as superior to that of the best manual system. The problem has therefore resolved itself purely into an economic one, the question for settlement now being, "Is the automatic system as economical as the manual"? Even this question cannot be answered, although it may be discussed in general terms, and it is necessary to consider each case on its merits.

Assuming for a moment that the costs of automatic and manual switching be precisely the same, and accepted that the service of the former is superior, the first questions which arise are (1) What, if any, is the value at which the improved service of the automatic

may be assessed? (2) Assuming that subscribers are to be served at cost, and no more, will they be willing to pay that increased cost for the improvement brought about by the introduction of automatic working? The improvement will be one benefiting the user, and the value thereof might be expressed in time saved to the subscriber.

The capital cost of automatic equipment has in the past been, and still is, greater than for manual, but with the mass production which would follow largely increased demand, there is prospect of reduction in capital cost, which might perhaps bring it to a figure at least comparable with that of manual equipment. But even if the cost of exchange plant remains higher for automatic than for manual, there are compensating features in favour of machine switching which are of great importance and therefore merit serious consideration.

The practical trials of automatic working made in this country have hitherto been of the nature of a demonstration of the practicability of automatic working, ascertaining the attitude of the telephone using public thereto, and obtaining costs of running the equipment. In no case yet has a scheme for automatic working extended to the full equipment of a multi-exchange area and therefore full scope for play of the economical advantages to be gained from its adoption on a large scale has not been given. The practicability of automatic service now demonstrated in the manner indicated, and assuming the relative costs of automatic and manual switching to have been determined, the remaining costs which will be the deciding factor can be readily ascertained.

Besides the advantages of improved service mentioned and which cannot altogether be left out of account, the following factors enter into the question :—

(*a*) Cost of operators' wages saved,
(*b*) Cost of land, buildings, staff accommodation, furniture and fittings is less, and
(*c*) Saving may possibly be effected in line plant.

Against the cost of operators' wages saved must, of course, be placed the extra cost, if any, of maintenance of the more complex and active apparatus. As the complete equipment for an automatic exchange occupies less space than equipment for manual of equal capacity, there is saving in ground space and cost of building,

and the latter is subject to further saving by the curtailed staff accommodation required. But it is the line plant perhaps which offers the greatest field for examination in pursuit of economy.

Owing to the certain and rapid operation of the automatic system, it is possible to work groups of junction circuits at their maximum efficiency. The rapidity of operation between one exchange and the other is no less than that between switches situate in the same exchange; consequently a group of exchanges may, in so far as speed of operating is concerned, be regarded as a whole, and the disadvantages and delays introduced in manual junction working entirely disappear. Therefore the system operates to permit the use of a larger number of exchanges than would be desirable in any area, with a manual system, with the result that the extent of the area of each exchange, and consequently the lengths of the subscribers' lines (which represent the most costly part of a subscriber's equipment in an exchange system) may, other factors permitting, be subject to reduction.

It is perhaps in this direction that the principal economies to be effected by the substitution of automatic for manual working may be secured, that is, in large multi-office areas.

Schemes for such undertakings involve the most careful investigation, not only in regard to the type, quantity and arrangement of the switching equipment proper, but also of the number and position of the exchanges and the lay-out of existing and new underground plant, proper regard being necessarily paid to the future requirements of the area as a whole. Such investigations require both skill and experience of a high order, and must necessarily occupy a more or less protracted period before satisfactory settlement can be arrived at.

A complication which arises lies in the fact that multi-office areas generally include exchanges of different sizes and system, and in varying stages of life and obsolescence, and not only do these affect the economic aspect of the question but—as it is obviously desirable to replace the older exchanges first and not entirely re-equip the whole at one time—it is essential that arrangements should be made for communicating satisfactorily between the new automatic exchanges and the existing manual exchanges during the period of transition.

A number of telephone areas were being considered for multi-office automatic working at the outbreak of war in 1914, but, like

many other matters of commercial importance to the nation, the matter had to be made subservient to the prosecution of the war and consequently was deferred, to be renewed only after the lapse of something like five years.

The present time appears to be a particularly propitious one for the consideration of such schemes in various parts of the country where, owing to the virtual abandonment by the National Telephone Company of development proposals extending beyond the date of expiration of its licence, and the almost immediate outbreak of war thereafter which precluded the Post Office from embarking on new schemes, a number of exchanges now exist of obsolete type and spent life and with their capacity exhausted; consequently their early replacement is imperative. The question of obsolescence and life of existing equipment in such cases does not therefore unduly complicate the schemes in prospect.

At the present moment a number of such schemes are approaching fruition and installation of equipment has been commenced.

Table 21 gives particulars of the various automatic exchanges on order by the British Post Office as at April 1924.

An interesting paper treating exhaustively of the automatic equipment of multi-office areas, entitled "The Telephone Service of Large Cities, with special reference to London," by E. A. Laidlaw and W. H. Grinsted, was presented before the Institution of Electrical Engineers on May 15th, 1919.

A three-volume publication, entitled "Automatic Telephone Systems," by William Aitken, is a recent and up to date work dealing with several systems of machine switching now in vogue; a still later publication is Mr. H. H. Harrison's "An Introduction to the Strowger System of Automatic Telephony."

CHAPTER XXI

LEGISLATION AND ITS APPLICATION

LEGISLATION is a factor which throughout the history of telephony in this country has exercised a most important influence upon and, therefore, cannot be readily dissociated from the technical and commercial development of the telephone.

In Chapter III mention is made of the important legal decision arrived at in the case brought by the Attorney-General against the United Telephone Company, that the telephone was a telegraph within the meaning of the Telegraph Acts of 1863 and 1869, and which had the effect of vesting in the Postmaster-General a monopoly in administration of the telephone service. Allusion is also made to the fact that the telephone companies, although inclined to dispute the judgment and to carry the matter to appeal in a higher court, eventually decided to continue the telephone business under licence of the Postmaster-General.

In the first licences which were granted conditions were imposed which the licensees considered to be of an onerous nature and such as would interfere with their prospects of conducting profitable business. A draft of one of the early licences is given in Appendix B.

The Government at that time was naturally somewhat perturbed at the prospect opened up by the introduction of the telephone of depletion of the revenue derived from the telegraphs, secured at a price much above their real capital value. The conditions stipulated by the Postmaster-General to which the telephone companies took exception were imposed with a view to the public benefit and for the sole purpose of safeguarding the telegraphs.

The clauses included in the original indentures which gave the companies cause for most concern were those in which the following stipulations were made :—

(1) Area of operations to be restricted to a radius of three, four or five miles from a fixed centre.

(2) Non-subscribers not to be permitted to use the telephone service.
(3) A royalty of ten per cent of the gross receipts from the exchange service to be paid to the Postmaster-General.
(4) Transmission of telegrams by means of an exchange telephone not to be permitted.
(5) The company was bound to sell or procure to be sold and deliver or procure to be delivered to the Postmaster-General telephones and other telegraphic apparatus similar to those they employed.
(6) The company was under an obligation to grant or procure to be granted to the Postmaster-General from time to time as might be required licences entitling him or persons or companies on his behalf to manufacture telephones and other telegraphic apparatus in accordance with specifications of any letters patent relating thereto respectively the property of or under the control of the company in consideration of payment by the Postmaster-General of the royalties.

Some considered that the terms and conditions included in these licences were just and such as were necessary in the interests of the telegraph service, some were of the opinion that an unhampered development of the telephone service could only be assured by the Government itself assuming responsibility for the telephoning of the country; others favoured private enterprise and a relaxation of the conditions under which the companies were administering the service.

These and other various views were vehemently expressed in the newspapers. The Government was inveighed against both for the action it had taken and the action it had not taken and the companies were held up to execration both for what they did and for what they had left undone. So commenced at an early date in the history of the telephone in this country, the agitation against the service, against those who conducted it and those who regulated it, an agitation which in various forms has continued intermittently even up to the present date, irrespective of the authority in whose hands the administration of the telephone service has been vested.

The Postmaster-General did not grant licences indiscriminately and applications for licences were in some cases refused. In declining to grant a licence to the British and Irish Electric Works Company for the establishment of telephone exchanges in

twenty of the largest towns in England, the Postmaster-General, in January 1882, expressed the view that it was generally recognised it was not in the public interest that several rival exchanges should be established in one town, an important condition of exchange systems being that every subscriber should be able to communicate with every other subscriber.

The Postmaster-General was averse at this time from issuing licences to companies to establish exchanges in towns where exchanges were already working. In the House of Commons on July 17th, 1882, the Postmaster-General announced that he had come to the conclusion that it would not be in the interests of the public to create a monopoly in relation to telephonic communication and that he was prepared favourably to entertain proposals made by responsible persons and to grant new telephone licences under conditions which might be regarded as giving adequate protection to the public and to the Department. A licence issued by the Postmaster-General to establish a telephone exchange would, however, confer no special power whatever to erect poles and wires on or to place wires under any highway or private property, neither would it confer any authority to carry on telephone business with any instrument the use of which would be an infringement of any patent.

On the 12th August 1882 the Postmaster-General announced in the House of Commons that,

> "Persons who were investing in Telephone Companies with the idea that they would some day be able to get favourable terms from the Government should at once know the truth, which was this,—that he did not think there was the smallest chance that the Government would ever buy up the rights of these companies.
>
> "The policy which they intended to adopt was that of allowing free competition,—competition amongst private companies, and the competition of private companies against the Post Office. After a time the public would be able to judge as to who did the telephone business best and if this experience proved favourable to the Government, they would have beaten the private companies in the fair open field of competition and would occupy the ground without any claim whatever for compensation or the purchase of rights."

The circumstances associated with the first attempts to establish a telephone service in Portsmouth are not without interest.

Although apparently the Postmaster-General had expressed his willingness to grant the necessary licence to the United Telephone Company, it appears that certain conditions were imposed which the company either declined or were extremely loth to accept. Eventually, through the instrumentality of the United Company, a deputation consisting of members of Parliament for Portsmouth, several members of the Portsmouth Town Council and the local Chamber of Commerce waited upon Mr. Fawcett, the Postmaster-General, on February 20th, 1884, with reference to the establishment of telephone service in their town. The deputation expressed anxiety to secure similar facilities in Portsmouth to those granted to Liverpool, Bristol, Birmingham, and other large places where the telephone was originally established at an early date. It was pointed out that there were certain material differences between the conditions imposed by the Post Office for the use of telephones and those offered by the United Telephone Company. The former charged £14 10s. for a half mile and £18 for over half a mile, while for any distance under a mile the company would only charge £12. They would also establish convenient exchange centres at various points instead of having one office only as the Post Office did.

The specific object of the deputation does not appear to have been clearly expressed, or was not published, but in reply to the representations of the deputation the Postmaster-General said, in effect, that the policy he had always maintained was not to enforce telephonic communications being supplied by the Post Office, but to allow the public to choose for themselves, whether a private company or the Post Office should assume responsibility for the telephone service. The important question raised by the deputation was not whether the supply should be through the Post Office or private enterprise, but what were the conditions necessary to attach to a licence given to a private company. The contention of the deputation he understood to be that he had allowed telephone licences to be given to certain towns, and that at a certain period different conditions were introduced, and that in future licences new conditions were to be enforced.

After the trial, in which it was decided that the telephone was an infringement of the telegraph monopoly, it was decided to allow such companies as had already established exchanges to continue under certain terms thought necessary to protect the

interests of the revenue. Other licences were afterwards applied for, and in view of statements made, that certain companies were being given a monopoly, it was necessary to reconsider the policy.

Consequently it was agreed that any town might have a licence for a company under certain conditions which would give proper protection to the public, and enable the Department to come in at any moment to protect the interests of the public with regard to telephonic communication in case any of the licensed companies had taken improper advantage of the privileges conferred upon them. Mr. Fawcett, the Postmaster-General, went on to say that the clauses to which objection had been raised had been inserted in the agreement for that purpose. The clauses had been accepted by other companies, and he was willing at the moment to give them an exchange on those terms. It was not his wish to establish Post Office exchanges and cut out private enterprise.

In a subsequent communication, the Postmaster-General offered to establish a Post Office telephone service at rentals of

£21	10*s.*	0*d.*	for one mile radial distance.
19	0*s.*	0*d.*	for three-quarters of a mile radial distance.
16	5*s.*	0*d.*	for half a mile radial distance.
14	10*s.*	0*d.*	for a quarter of a mile and under.

The report of the deputation together with the Postmaster-General's communication were considered at a special meeting of the members of the Portsmouth Chamber of Commerce, and the Committee then appointed to deal with the matter drafted a letter to the Postmaster-General, in which it was stated that the rates quoted were prohibitive, and such as would prevent a successful exchange being established in Portsmouth; the opinion was expressed that a price of more than £15 would not secure sufficient subscribers to make the exchange a success.

Although particulars of the clauses to which objection had been taken do not appear to have been publicly announced, it seems clear that they were those which related to the acquirement by the Postmaster-General, from the licensee, of telephone apparatus, the patent rights for which were owned by the United Company. Copy of a draft of the indenture prepared by this time for execution between the Postmaster-General and private companies desiring

to enter the telephone business is included in Appendix B, Clauses 17 and 20, which placed the Postmaster-General in a position to secure as many telephones manufactured under the patent rights held by the United Company as he might require, were unacceptable to that company, and placed the subsidiary and other companies in a very peculiar position; in fact the condition imposed was such as the latter were unable to satisfy.

In the House of Commons on Thursday, May 22nd, 1884, Mr. Gray raised vigorously the question, with other questions relating to the telephone service, of this alleged unfair condition. He stated that a few years earlier the Postmaster-General granted licences on the mere condition that a royalty of 10 per cent. should be paid. Suddenly the policy was changed, and it was given out that no licences would be granted unless the companies who applied for them should sell to the Postmaster-General as many instruments as were wanted. This policy of strangulation had been adopted about two years ago, and not only had remonstrances been made by the companies, but deputations from various towns waited upon the Postmaster-General in vain. While the Post Office had been working the telephone during the last two years they had only got 700 subscribers at their various telephone exchanges. For those 700 subscribers they had 5000 telephone instruments, and so far were they from being apprehensive of the supply of instruments running short that they had been selling them at a profit and, further, the Post Office, by a contract entered into with the United Telephone Company, had a right to a supply of 15,000 more, that was to say, they had under their control 20,000 instruments in all.

Mr. Fawcett, in answering, said he should much regret if any word he said in reply was in any way taken to separate himself from the permanent officials of the department, and he accepted full responsibility for everything that was done. All sorts of charges were brought against the officers of the Department, as if they had some private motive to serve, but they had no interest except the interest of the Post Office and of the public. The number of applications for telephone exchange licences since the institution of the new conditions, requiring each company receiving a licence to undertake to sell instruments to the Postmaster-General, had been 77, and the number granted had been 8. The new condition was imposed solely for the purpose of protecting

the public, and was not intended to check the establishment of telephone exchanges.

He was free to confess that it had been shown by experience that the new condition which he thought it had been necessary in the interests of the public to impose two years ago had checked the development of private telephone enterprise. He had not intended that this should be the effect, and had for some time been considering whether, with due regard to the public interest, it could be in any way modified. As soon as he was in a position to come to a decision on the point there would be no delay in making it known.

Some particulars relative to the operation of the two clauses referred to in connection with the issue of a licence to the Northern District Telephone Company are given in Chapter VI.

Indicative of some of the extreme views which were expressed in regard to the telephone question at this time, the following extract from the *Western Morning News* of July 17th, 1884, which commented upon the situation relating to the telephone exchange service at Plymouth, is quoted :—

"Much was hoped from placing so able and enlightened a statesman as Mr. Fawcett at the head of the Post Office, and proportionately great is the disappointment at finding that, in the matter of the telephone and telephone exchanges, there is nothing but procrastination, repression, and narrowness, resulting in financial failure and public inconvenience.

"In Plymouth, Devonport and Stonehouse, three years ago, there were 150 residents each of whom could speak to the other through a telephone exchange. But official pique on the part of the Post Office put a stop to this, and established a so-called Post Office exchange. The number of members has never exceeded 46; and it has now fallen back to 42; and several other subscribers have given notice to leave unless the numbers are so increased as to make the exchange really worthy of the name.

"Plymouth is but a sample of nearly every other town where the Post Office monopoly has taken effect and Post Office exchanges have been instituted. But for the Postmaster-General's veto, a real and useful exchange might be established in the three towns next week, at a subscription far less than that which the Post Office demands."

As a contrast to this somewhat caustic comment upon the administration of the Post Office telephone system, the views

expressed in a leading article published in *The Electrician* for October 20th, 1883, are not without interest. In this article *The Electrician* commented on a paper, read by Mr. W. H. Preece at a recent meeting of the British Association, in which some account was given of the activities of the Post Office Telegraph Administration in providing an efficient system of telephony. Generally the Government telephone service was eulogised at the expense of that of the companies, and the following passages are quoted :—

"After reading the Government officer's report—for so in a sense it may be regarded—one cannot help saying Happy is the place that the telephone companies despised.

"In defiance of all warning, however, the telephone companies pursue their reckless course, with seemingly no guiding principle but the exigency of the moment or the forthcoming shareholders' meeting. Their overhead wires have assumed proportions which constitute them a public danger, as well as a national disgrace, a great portion of the city being rendered, we will not say hideous, but ridiculous by their presence.

"It is plain to be seen that these countless wires and cables have been erected without any system whatsoever, but are as erratic in their course, and as impertinent in their intrusion, as summer cobwebs drifting on the breeze. Less than half of the present number would suffice if erected on any rational plan; and if we must have overhead wires, surely it would be cheaper, as well as more decent, to band them together cablewise, crossing the streets at right angles, and as rarely as possible, rather than to work with the limited appliances of a spider, and without any of his brains.

"The apparatus is miscellaneous and in some instances a long way from being the best, so that customers very often find themselves in front of an instrument they do not know how to use. The boon conferred upon the commercial classes by the rapid extension of telephonic communication is undeniably very great; but it has been hurried forward in such a fashion that disappointment is very close at hand. Instead of being compelled, as a State-managed business would be, to give the public the very best service possible, these private companies have run up a system as bad as could well be devised, and one that is certainly doomed to fail."

By the end of 1883, the local telephone service administered by the several companies had grown considerably, and the necessity for the introduction of more comprehensive facilities for long distance service was apparent. The companies were unable

themselves to extend their trunk line systems, which at that time were of exceedingly small dimensions, and the arrangements whereby trunk lines were provided by the Post Office for the companies did not appeal to them. Consequently development of the trunk service was not encouraging. Applications made by the telephone companies to extend the radius of their operations were not viewed with favour, and in the few cases granted, a royalty of 12½ per cent. on all wires extending beyond the originally stipulated radius was charged. Transmission of telegrams to and from post offices was permitted to subscribers to the Post Office telephone system and similar privileges were granted to subscribers to the companies' systems, on payment annually by each firm desiring the privilege of £5 5*s*., which sum did not of course include the ordinary telegram charges.

These conditions caused a good deal of heart-burning to the companies, and as they were not considered to be conducive to the development of their respective businesses, agitation for the purpose of securing their modification was commenced.

In the spring of 1884 a memorial was presented to the Postmaster-General by the Edinburgh Chamber of Commerce, pleading that the Government should bestow such facilities as would tend to encourage and develop the telephone system of the country, without prejudicing the telegraph revenue. The memorial was followed up by questions in the House of Commons.

The answer to the controversy which was going on throughout the country, and to the representations of the telephone companies respecting the terms of their agreements with the Postmaster-General, came in reply to a question in the House of Commons on June 24th, 1884, when Mr. Fawcett, the Postmaster-General, suggested that the telephone companies should meet, and endeavour to come to a conclusion on the modifications of the terms of agreement, which in their opinion would meet public requirements, and that, should the suggestion be acted upon, their communicated proposals should receive careful consideration, with every desire to allow the greatest freedom possible to telephonic communication which was compatible with due protection of the interests of the revenue.

In due course the United Telephone Company and its affiliated companies submitted certain proposals, and four other companies forwarded statements of their views which, except in one par-

ticular, did not vary in any important respect from those of the United Company.

These suggestions were duly considered, and on Thursday, August 7th, 1884, an important announcement respecting the terms under which the telephone companies were empowered to administer the telephone service was made by the Postmaster-General. The occasion was the vote to complete £1,734,589 for the requirements of the Post Office telegraphs, and a discussion on the policy of the Post Office with regard to the telephone companies followed.

Mr. Fawcett stated he had come to the conclusion that in order that the public might enjoy the facilities with regard to telephonic communication, which, in his opinion, they might fairly claim, it was desirable to give greater freedom to private enterprise, by relaxing some of the conditions contained in the licences granted to private telephone companies. The terms which, after giving due consideration to the proposals received from the several companies, the Government were prepared to offer were announced, and were briefly as follows :—

(1) That the Government should reserve the right either to carry on telephone business itself, or to give licences to any responsible persons to carry on such business in any part of the country, whether any previous licence had been granted for such part of the country or not.

(2) That the condition that the companies should furnish the Post Office with an unlimited supply of every patented instrument used by them should be abandoned.

(3) That as the extension of the radius to fifteen miles asked for by the companies would involve, in principle, just the same objections as fixing the radius as at present at four or five miles, no limitations of radius should be maintained.

(4) That with the abolition of any limit of radius and consequent extension of areas, the distinction between the conditions on which the companies had hitherto been allowed to use trunk and exchange wires would not be maintained, the companies being in future able to provide themselves with trunk and exchange wires alike.

(5) Call offices should be allowed for the transmission of oral communications.

(6) Having regard to these concessions, and to the desirability,

as far as possible, of securing simplicity of accounts between the Post Office and the companies, the royalty of 10 per cent. then paid on gross receipts should be extended to their receipts from private wires.

(7) That the Post Office should incur no obligation to provide wayleave, or to erect wires for the companies.

(8) That in order to maintain the distinction between written telegraph messages and the spoken communications made by means of the telephone, the telephone companies should not accept or deliver any written message at any point.

Mr. Fawcett undertook that as soon as the existing licences were returned they should be amended so as to carry out the foregoing proposals.

Considered collectively, the terms proposed by the Government were distinctly favourable, and a great improvement on the old ones, but the companies were opposed to acceptance of the provision that royalty should be paid on private wires, the private wire business at that time being much greater in proportion to exchange business than it is at the present day. Consequently, upon certain representations being made, the Postmaster-General, in September 1884, notified the companies that, in addition to the important concessions announced on August 7th, he was prepared to abandon the claim for a royalty of 10 per cent. to be paid to the State on private wires, and also that the privilege of connecting the various telephone systems with the postal telegraph offices would be conceded. In due course the companies signified their assent to the acceptance of the new conditions, the old indentures were surrendered, and new ones issued embodying the modified terms.

The principal provisions of the new licences are quoted in Chapter XVIII, and a copy of a draft of one of the licences is given in Appendix C.

The effect of these new agreements was to widen considerably the field of work of the telephone companies, and consequently development of both local and trunk telephone service was greatly accelerated.

In Chapter III the agitation which commenced in London (for which reason the subject is dealt with in that chapter) and eventually extended to the Provinces, against the rapidly growing system of overhead wires, and for the introduction of measures

for its regulation and control by public authorities, is dealt with, and the litigation which transpired in May and June 1884 between the Board of Works for the Wandsworth District and the United Telephone Company is referred to. The decision arrived at by the Court of Appeal did not, however, end the matter.

In Chapter VI reference is made to the fact that, in 1884, the United Telephone Company promoted a Parliamentary Bill for the purpose of vesting them with certain powers for the installation of external line plant, but that owing to the opposition encountered the Bill had to be withdrawn.

In 1885, a further attempt was made to secure similar powers by the presentation to Parliament of a second Bill.

Eventually the House of Commons, impelled to take action by the continued agitation of the Press, the public and various authorities against the uncontrolled growth of the overhead line system, and of the several companies for the acquisition of statutory powers for the installation of line plant, appointed a Select Committee to consider the law relative to the control over telephone, telegraph and other wires. In view of the appointment of this Select Committee the United Company withdrew the Bill which at that time was before Parliament.

After taking the evidence of a large number of witnesses, including independent experts, the engineer and other representatives of the United Telephone Company, together with representatives of the vestries and the aggrieved householder, the Committee issued a report in May 1885, the gist of which was as follows :—

1. The danger to the public from overhead wires had been greatly exaggerated.
2. Accidents proved in evidence were few and insignificant.
3. Some change in the law relating to control of overhead wires was desirable in view of the probable development of the telephone system.
4. Owing to the great and growing public convenience and capability of development of the telephone service, a course which would materially hamper its extension could not be recommended.
5. It was recommended that the erection of overhead wires should be continued, subject to proper supervision and regulation, and that permission should be given to pass wires over property without the owners or occupiers having the right of prohibition, but that no vested interest or easement should be conferred in the enjoyment of this facility.

6. Bye-laws for the regulation of all wires as to substance, length of span, durability and other matters, and for their identification and inspection, should be made for the whole of London by the Metropolitan Board of Works, for provincial towns by the Corporation, and for rural districts by the local authority in each case, subject to the sanction of the Board of Trade.

In June 1885 it was reported that the Government did not intend to follow up the recent report of the Select Committee on overhead wires by any legislation, considering that the recommendations passed by the majority of the Committee were impracticable, and would invade private rights to an extent for which the Government was not prepared to make themselves responsible.

In 1888 the United Telephone Company followed up their previous efforts to secure the aid of legislation for the installation of external plant, and a Bill, largely based on those recommendations of the Select Committee of 1885 which particularly concerned the private companies, none of which had been acted upon, was again brought before Parliament.

In June 1888 a deputation waited upon the Postmaster-General, Mr. Raikes, requesting him to support reference to a Select Committee, of the Bill promoted by the United Company. Mr. Raikes was reported to have stated on this occasion that the telephone patents would expire shortly, and that the Government might then be able to deal with the telephone question. It was decided to let the matter drop for that session, and for the third time the efforts of the United Company in this connection came to nought.

Mr. Raikes' declaration in respect of possible Government action upon expiration of the telephone patents was in some quarters looked upon as indicative of the possibility of unfair advantage being taken of the companies who had hitherto been the pioneers of telephony in this country, and who had necessarily had to bear the heavy expense of acquiring important patent rights.

The ruling of the court that the telephone was a telegraph within the meaning of the Telegraph Acts which vested in the State the monopoly of the telephone service was never legally disputed, although there were lawyers and others competent to express an opinion who, at the time, held the view that had

the United Telephone Company carried the matter to appeal the decision of the Court of First Instance would have been upset. Because the Government were thus legally constituted the guardians of the telephone service, there were many who considered that the telephone system should be State owned and administered by the Telegraph Department of the Post Office. Others, on the contrary, held the view that the telephone might best be developed by private enterprise.

These differences of opinion continued to be ventilated at intervals in the Press and elsewhere during the period 1880–1890, and towards the latter part of that period these discussions were accentuated by a general expression of dissatisfaction with the telephone service, and the high rates charged, principally directed against the London administration.

In February 1888 the Associated Chambers of Commerce passed a resolution in favour of Government control of telephone communication.

On June 4th, 1889, a question was asked in the House of Commons respecting the tactics of the financial group commanding the telephone systems of the kingdom and the exploitation of the public, and the Postmaster-General was urged to avail himself of the right to establish, extend, maintain and work a telephone system such as would bring the advantages of the invention within reach of the people. The Postmaster-General, Mr. Raikes, replied that the matter was receiving serious attention.

In the House of Lords on July 4th, 1889, the Duke of Marlborough, who was greatly interested in the promotion of the New Telephone Co., Ltd., in calling attention to the amalgamation of the telephone companies which was then pending (dealt with in Chapter IX) moved that consent be withheld to the establishment of such a monopoly until the question had received consideration by a Joint Committee of both Houses of Parliament. He referred to the nuisance of overhead wires, and the disadvantages of private ownership, and expressed the view that "No city in civilised Europe was so behindhand as London in telephonic communication and certainly none so spoilt and disfigured by wires running in all directions." Eventually the Duke withdrew his motion with a view to its revival at the beginning of the next Parliamentary Session.

Early in 1890 the Edinburgh Chamber of Commerce addressed a memorial to the Postmaster-General, advocating purchase of the telephone system by the Government at the earliest possible date, and a similar memorial was addressed to the Lords Commissioners of Her Majesty's Treasury.

In answer to these and other views which were freely expressed during the period in question, the Postmaster-General was reported to have announced early in 1888, and again in June 1890, that the Government had decided not to purchase the undertakings of the telephone companies. Questions relative to the matter were asked and answered in both Houses of Parliament.

Towards the end of 1891 a report that the National Telephone Company had decided to make application to Parliament for statutory powers authorising them to erect wires over streets and other public places, and to break up streets within the United Kingdom for the purpose of laying telephone wires, led to a renewal of the agitation for Government ownership. In due course two Bills for the object named, one promoted by the National, and the other by the New Telephone Company, the latter being at that time actively engaged in making preparations for the establishment of their contemplated telephone system in competition with the National Telephone Company in London and other large towns, were brought before Parliament.

These Bills sought to invest the two companies named with powers which were considered to be of far-reaching importance; in brief, they were, broadly, to enable them to instal underground plant, to erect posts on public roads and to open up thoroughfares for that purpose, to erect posts on land and to pass wires over estuaries and branches of the sea. The consent of roadway authorities in London was to be necessary, and also in towns with upwards of 30,000 inhabitants. Petitions against the National Telephone Company's Bill were presented by more than 170 local authorities, nearly 50 gas, water, railway and electric supply companies and some 10 property owners. Against the New Company's Bill approximately 60 local authorities, 20 companies, and 8 property owners lodged objection.

On February 22nd, 1892, the London Chamber of Commerce convened a meeting to consider the general position of the commercial community, in regard to the telephone service of London

and the Telephone Bills before Parliament. The meeting was well attended and a lengthy discussion ensued in which various views were expressed. The meeting was, however, divided into two schools of opinion, one evidently desirous that the telephone system should be in the hands of the State, and the other that statutory powers should be conferred upon the private companies.

After a resolution had been proposed, and an amendment moved, in which the extreme views of the meeting were respectively embodied, the chairman, Sir Albert K. Rollit, M.P., a member of the board of directors of the New Telephone Company, very adroitly contrived to word the resolution ultimately put to the meeting in such a manner as to satisfy the contrary opinions which had been expressed.

The resolution, which was unanimously carried, was as follows :—

"That in view of the importance of the telephone industry and the fact that two separate companies have Bills before Parliament, this chamber should appoint a deputation to apply for an interview with the Postmaster-General and express the view of the Chamber as to the supreme importance of Her Majesty's Government bringing a General Powers Bill into Parliament, so as to afford facilities for the development of the telephone, not only in the Metropolis, but also with reference to intertown services all over the country, whether by private companies or the Government themselves."

The deputation, introduced by Sir Albert Rollit, waited on the Postmaster-General on March 21st, 1892. The Postmaster-General gave the deputation to understand that the matter was one to which the Government had devoted much attention, and undertook to make a general statement when the two Bills came on for second reading on the following day, as to the policy of the Government, and the scheme which had been formed for the promotion of the objects represented by the deputation.

In the House of Commons on Tuesday, March 22nd, 1892, on the motion for the second reading of the "New Telephone Company Bill," Sir James Fergusson, the Postmaster-General, redeemed the promise made to the London Chamber of Commerce deputation, and stated the course which the Government found it necessary to take with regard to the Bill, and the policy which they intended to pursue regarding the very important

questions concerning the telephone system. He explained that, except in one particular, the Bill under consideration sought to obtain for the New Telephone Company statutory powers similar to those provided for the Post Office by the Act of 1863. Thirteen companies had been granted licences extending over the whole kingdom. The telephone interest was in a different position from that of the gas, water and electric lighting companies and so forth, because none of these touched or trenched upon the prerogative of the Crown, telephones being the monopoly of the Post Office. He opposed the second reading of the Bill, as also the Bill promoted by the National Telephone Company, which latter sought powers much wider than any ever asked for by the Post Office, in view of what he believed to be the prevalent opinion, and of the constant policy of the Post Office. Owing to the failure of the intentions of the Government, the telephone system had made less progress in this country than perhaps in any other country in Europe; the form of licence issued by the Post Office had something to do with the hindrance of the telephone system. Real danger of the valuable telegraph property being injured by the telephone, without due provision, was proved by the fact that wherever the telephone system had been effectually developed, the growth of telegraph revenue had been checked. Concessions which might be made without corresponding provisions for the protection of the public revenue would be very dangerous, for if the telephone companies were in communication with all the large towns and sent messages all over the country, undoubtedly the system would to a large extent supersede the use of the telegraph, and consequently largely diminish the telegraph revenue. Therefore it was an essential feature in the scheme, if carried out, that the Government should have possession of the trunk wires, in order that the public might have their portion of the sum paid for the message in the same way as telegrams.

Sir James went on to say that wherever the Local Authority were satisfied that a telephone exchange was desirable in the area, and the Government were satisfied that the licensees were in a position to carry out their undertaking, and that it was in the public interest desirable that they should have a licence, then they would be granted a licence for that area. It was his intention, on the part of the Government, to move in a few days

for leave to bring in a Bill to confer additional powers on the Post Office in regard to telegraphs and telephones. After short discussion the debate was adjourned to that day week.

The supporters of the policy of purchase by the State, of the entire telephone system of the country, did not approve of the action of the Government in acquiring only the trunk lines, regarding it as a foregone conclusion that purchase of the local exchange systems would be necessary in the public interest at a later date, and deprecated the taking of what was described as "two bites at the cherry."

On March 29th, 1892, Dr. Cameron moved in the House of Commons :—

"That the Post Office system of granting licences to private telephone companies, having resulted in the restriction of telephonic communication in this country, and a costly and inefficient service, this House is of opinion that alike in the interest of the postal telegraph and the telephone service, the telephone monopoly possessed by the Post Office should be worked directly, and in connection with the Postal Telegraph Department."

Sir J. Fergusson, the Postmaster-General, in opposing the motion, instanced the circumstances in which the Government had resolved not to acquire the capital of the companies, but to permit them to carry on the service under their licence; he proposed that telephone communication should be established as widely as possible between one part of the country and another; there was no reason why new companies should not be formed, and if the existing companies did not supply the wants of the people, the Post Office would come in and establish exchanges, as at Newcastle and Hull. The possession by the Government of the trunk lines would encourage competition.

Dr. Cameron's motion was lost by a majority of 58.

The Postmaster-General's proposals were embodied in a Bill laid before the House on May 26th, 1892.

After consideration by Her Majesty's Treasury of the Postmaster-General's proposals for giving effect to the policy dictated by the Government, a Treasury Minute upon the "Proposals for the Development of the Telephone System in the United Kingdom," which supported the scheme prepared, was laid before Parliament on May 27th, 1892.

The Minute stated in effect that the proposals had as their object the expansion of the telephone system called for by public opinion, and the necessities of commerce. It was impossible to continue the present system under which the telegraph revenue was seriously suffering, while, on the other hand, the expansion of the telephones was checked in a manner which could not be permanently maintained. The proposals were calculated to enable the telephone companies and the Post Office to co-operate. Unless the trunk wires were in the hands of the State, a monopoly injurious to the public interest would eventually ensue, to the advantage of the company which first laid down such trunk wires. The companies were to abandon their right to construct trunk wires, and the Post Office should purchase from them such as had been erected, and in addition provide additional trunk wires to build up a complete system.

It was proposed further to connect up Great Britain and Ireland by a trunk cable, and that the whole system should be open to use by any member of the public, and not be confined to subscribers of the companies. The exchanges of the companies were to be connected with Post Offices, in order that subscribers might avail themselves of the trunk telephone system, and telephone messages be dealt with through the existing channels of the Post Office communications. The Post Office were to provide underground wires, at agreed rent, to connect together exchanges of a company within one and the same area. The use of railways, canals, etc., where the Post Office possessed exclusive rights of way, was to be permitted at 1*s.* instead of 20*s.* per mile of wire as before.

No further licence for the whole of the country was to be granted, and even for a licence to establish an exchange in a particular town no application was to be entertained unless a formal resolution in its favour had been passed by the Corporation or other Municipal authority, and evidence given that sufficient capital was forthcoming. In this way it was intended that competition would not be excluded, but a check would nevertheless be imposed on the formation of companies whose sole object was to force existing licensees to buy them up. A condition of any new licence issued would be that metallic circuits were to be used exclusively. The royalties payable to the Government were to be unchanged.

Clause (21) of the Treasury Minute read as follows :—

" In conclusion it may be stated that the intention is to meet as far as possible the views of municipal authorities, to aid the telephone companies in the improvement of their exchange system, to place additional facilities at the disposal of the public, and to establish trunk wires between the more important towns throughout the country."

The Postmaster-General's Bill was referred to a Select Committee, which issued its report on June 16th, 1892, and after subsequent amendment the Bill received the Royal Assent on June 28th, 1892.

Although the National Telephone Company anticipated that the measure would endow them with adequate powers of wayleave for erecting wires overhead and laying wires underground, nevertheless the Bill as finally passed made it incumbent upon them to secure the consent of the Municipal or other public authority, and their position in this respect was therefore little improved; they were not, however, prepared to combat the Government, and, after some representations had been made in the proper quarter, it was decided that nothing further could be done; consequently on August 11th, 1892, heads of arrangement for the sale of the trunk wires were initialled by Sir James Fergusson, the Postmaster-General, and Mr. J. S. Forbes on behalf of the company.

To give legal effect to the arrangements which had been made for purchase by the State of the trunk lines owned by the National Telephone Company, Mr. Arnold Morley, the then Postmaster-General, submitted to the House of Commons, in August 1894, a draft agreement.

Very persistent efforts were made to prevent the agreement being completed, although it was pointed out by Mr. Morley that the bargain had already been made, and that the agreement in question was necessary merely in order to legalise the transaction.

On January 24th, 1895, representatives of the Municipal Corporations Association interviewed the Postmaster-General protesting against the agreement being entered into, and on February 4th, 1895, a further deputation from the London County Council waited on the Postmaster-General for a similar purpose, stating their objection that an opportunity had not been afforded

for discussion of the provisions of the Bill. Deputations from Edinburgh, Glasgow and Aberdeen were also received upon the subject of granting licences to Municipalities.

There appeared to be some concern that the Government had attempted to rush the Bill through the House, and that the terms of purchase, and the powers to be conferred upon the company, were highly prejudicial to the community.

On March 1st, 1895, Mr. Benn moved in the House of Commons :—

"That a Select Committee be appointed to consider the proposed draft agreement between the Postmaster-General and the National Telephone Company, and report with reference to the monopoly which may thereby be created; the granting of telephone licences to Municipalities, and generally, on the future policy of the Post Office with reference to the extension of the telephone service; that the Committee have power to call witnesses and send for papers and records."

Considerable discussion ensued. The Postmaster-General, Mr. Arnold Morley, explained the situation at some length, and finally stated that the Government were willing that the matter should be considered by a Committee, but instead of the words employed by Mr. Benn, he proposed to insert the following words :—

"That a Select Committee be appointed to consider and report, whether the provisions now made for the telephone service in local areas be adequate, and whether it is expedient to supplement, or improve, that provision by the granting of licences to local authorities or otherwise."

Mr. Benn's motion was negatived and Mr. Morley's amendment agreed to, and the first meeting of the Select Committee, of which Mr. Morley was chairman, was held on March 19th, 1895.

Voluminous evidence was taken which it is not necessary to recapitulate, but it may be mentioned that Mr. James Staats Forbes in giving evidence on Tuesday, May 21st, 1895, stated that on May 3rd the National Telephone Company addressed a document to its subscribers asking whether they were satisfied that the service supplied by the company was reasonable, and whether they approved of the service being undertaken by the London County Council. Of the replies received, 2346 expressed

unconditional satisfaction with the service, 266 expressed satisfaction with qualifications, 43 signed in favour of the London County Council and 36 declined to sign. Mr. Forbes also mentioned that 117 exchanges of the National Telephone Company, representing a total of 18,978 subscribers' lines, had already been fitted, or were in process of fitting with metallic circuit wires and switchboards and that complaints during the year 1894 were in the ratio of 0·73 per subscriber's line.

From the leading article in *The Electrician* for June 7th, 1895, which commented upon the evidence proffered to the Select Committee, the following has been extracted :—

" . . . Not a few personages who thought themselves authorities have left the Committee room emptied of their reputation, if not of their conceit. It is very easy to collect any number of complaints against the telephone system or for that matter against any human system whatsoever; but when men come forward with schemes of reform they should at least take the trouble to understand something of what they are talking about. Representatives of Municipalities, who are greatly to the fore just now, are very much lacking in this respect; and the National Telephone Company's contention, that its business would be worked less efficiently by municipal bodies than by private enterprise, found no little support in the character of the testimony offered by typical members of the former. . . ."

" What the telephone has suffered from hitherto has been, it may be confidently asserted, a species of parochialism gradually, it is true, developing on a bolder and more national basis, but still hampered and afflicted by the petty and narrow limitations under which its early years were spent. Nobody is particularly answerable for this; railways grew up in a similar way."

" Of the many ' progressive ' suggestions which came out into the light in the Committee room none was more prominent than that of municipal telephones. . . ."

" If a round robin could be got from all quarters we suspect that a majority could be obtained for voting the telephone an unmitigated nuisance which everybody would wish to see abated and perhaps even abolished altogether; and this not because of its defects but by reason of the demands it makes on the nervous energies of its users."

The Committee sat on eleven days between March 22nd and May 28th, and examined in all 31 witnesses. More than 5000 questions were put, and the evidence when printed filled a blue book of 370 pages.

The Select Committee's report was issued on June 25th, 1895, and the text of it was as follows :—

"Your Committee have examined numerous witnesses upon the matter referred to them, and have completed their evidence but have not, in view of the approaching dissolution of Parliament, had sufficient time to consider their report. They have therefore agreed to report the evidence they have taken to the House, and to recommend that a Committee on the same subject be appointed in the next session of Parliament, to consider and report upon the evidence already taken and, if necessary, to take further evidence."

The Committee's recommendation was never acted upon.

The agitation against the National Telephone Company and the service it gave, to induce the Government to take the telephone service into its own hands, and for Municipalities to be licensed to establish and work their own telephone systems, continued and waxed stronger. Questions were asked in the House of Commons, the pros and cons of the matter discussed and various views ventilated in the Press. To the numerous complaints made by the telephone-using public against the administration and high rental charges of the company was now added another, viz., that of unnecessary delays and unsatisfactory working of the trunk telephone system, which by that time was undertaken by the State.

In consequence of the repeated complaints made against the Glasgow telephone service, the defects from which it was alleged to suffer and the anxiety of the Glasgow Corporation to be licensed to undertake its own telephone service, the Lords Commissioners of Her Majesty's Treasury arranged for an inquiry to be held in Glasgow, which was opened by Sheriff Jameson in the Burgh Court Hall on Tuesday, September 28th, 1897. Evidence was given by Mr. James Staats Forbes, president, Mr. W. E. L. Gaine, general manager, and Mr. Dane Sinclair, engineer-in-chief to the National Telephone Company. The Glasgow Senior Magistrate and City Treasurer and a number of dissatisfied subscribers, some of whom represented business organisations, also gave evidence. The proceedings lasted eleven days and terminated on October 9th, 1897. Sheriff Jameson's report to the Postmaster-General was issued in November.

He came to the conclusion that the inefficiency of the telephone service in Glasgow was in a large measure due to the refusal of the Corporation to grant facilities to the company for the construction of an underground metallic system. He held that the objection of the Corporation was absurd, as was also the way in which some members of the Corporation spoke of the streets as being the patrimony of the Corporation. His inference was that the true cause of the refusal to allow the company wayleaves was, that the Corporation were resolved to establish a telephone system of their own by means of which they believed they would be able to extinguish the National Telephone Company altogether, and supply a better and a cheaper service. He considered that the rates were not unreasonable except for some of the outlying districts. He was prepared to state as his opinion, apart from the difficulty of the situation, that it was not expedient that the Corporation of Glasgow should be granted a licence because—

(1) "Common Good" funds could not be applied legally for the benefit of a limited number of citizens.

(2) It was inexpedient to have two telephone systems within the same area.

(3) The Corporation had not produced satisfactory evidence that they could successfully finance and work the proposed system.

In view, however, of the necessity for underground metallic conductors, and of the statement that the Corporation would never consent to the company being allowed to lay an underground system in Glasgow, Sheriff Jameson suggested that it would be expedient to grant to the Glasgow Corporation a licence, provided they were able to satisfy the Postmaster-General that, financially, the scheme was sound, and that they had the means of carrying it out.

The Secretary to the Post Office, in forwarding to the Town Clerk of Glasgow a copy of Sheriff Jameson's report, stated that, "... the Postmaster-General is advised that the Corporation, in the present state of the law, has no power to carry on the business of a telephone exchange, either within or outside the limits of the Municipality, and in these circumstances he is precluded from assenting to the wishes of the Corporation by issuing a licence."

In the House of Commons on Friday, April 1st, 1898, a debate on the telephone question engaged attention for several hours. It arose out of a resolution put by Mr. Caldwell practically censuring the Post Office for withholding licences from Municipalities. In the course of a somewhat lengthy speech, Mr. Hanbury, Financial Secretary, announced that it was proposed to appoint a Select Committee of the House, to confine itself to consideration of the legal aspect of Municipal telephone undertakings.

On the motion of Mr. William Walrond, in the House of Commons, on Monday, May 9th, 1898, a Select Committee was appointed " to inquire and report whether the telephone service is, or is calculated to become, of such general benefit as to justify its being undertaken by municipal and other local authorities, regard being had to local finance and, if so, whether such local authorities should have power to undertake such service in the districts of other local authorities outside the area of their own jurisdiction, but comprised wholly or partially in the same telephone area, and what powers, duties and obligations ought to be conferred or imposed upon such local authorities." The minutes of evidence taken before the Select Committee on the telephone service in the session of 1895, the report of the Commissioner, and the evidence taken before him in the inquiry which had been held in Glasgow, were referred to the Committee for consideration, in so far as they related to the subject of the inquiry pending.

The investigations of this Select Committee were even more exhaustive, and the proceedings more lengthy, than was the case in the inquiry of 1895. The Committee first met on Tuesday, May 17th, 1898, Mr. Hanbury, Secretary to the Treasury, presiding. There were in all twenty sittings, and the taking of evidence did not conclude until August 4th; the evidence, taken from numerous representatives of every interested body, was voluminous. Unlike the inquiry of 1895, however, the matter was, in this case, carried to an issue and the Committee's report, issued in August 1898, found that :—

(1) The telephone service was not of general benefit either in the United Kingdom at large or even in those limited portions of it where exchanges existed.

(2) That it was not likely to become of general benefit, either

in the country as a whole, or in existing or future exchange areas, so long as the existing practical monopoly in the hands of a private company should continue.

(3) As it had already become of much more general benefit in other countries affording less scope than was afforded by the United Kingdom, it was fitted to become in this country, if worked solely or mainly with a view to the public interest, a valuable instrument in further developing the trade and social life of the country.

The Committee considered that the trunk service, in the hands of the Government, was the most extensive in Europe, but that the privately managed local exchange service was much behind that of some Continental countries. It also considered that the right of the Government to compete was established in spite of the statements by Mr. Forbes, the President of the National Telephone Company, in his evidence to the effect that his company had relied upon pledges made to protect the company against competition.

Generally the findings of the Committee were summed up in the following paragraph of the report :—

" On reviewing the whole of the evidence your Committee is strongly of the opinion that general, immediate, and effective competition, by either the Post Office or the local authority, is necessary, and consider that a really efficient Post Office service affords the best means for securing such competition. We further consider that when, in an existing area in which there is an exchange, the local authority demands a competing service, the Post Office ought either to start an efficient telephone system itself, or grant a licence to the local authority to do so."

The final paragraph read :—

" Your Committee, in thus recommending a Post Office service, assume that it will constitute a real and active competition, and that concessions to the company not required by the agreement will cease. Such a competition should, in their opinion, be carried on by a distinct and separate branch of the Department, and in future be conducted under strictly businesslike conditions, and by a staff specially qualified for such a duty."

After due consideration had been given by the Government to the findings of the Committee expressed in their report, Mr. Hanbury, on Monday, March 6th, 1899, moved the following resolution in the House of Commons :—

"That it is expedient to authorise the issue out of the Consolidated Fund of a sum, not exceeding two millions, for making further provision for the improvement of telephonic communication, and to enable local authorities to raise or apply money for telephonic purposes."

In moving the resolution, Mr. Hanbury announced that the company had no intention whatever of extending their system beyond 1904, and for that and other reasons, which he gave, it was absolutely necessary that some other competitors should come into the field to supply the void between 1904 and 1911. His resolution asked for two millions of money to develop telephonic communication on the part of the Post Office, the first place to be given attention being London, in which area the Post Office was determined to compete at once, the question of wayleaves being the deciding factor in this case.

Municipalities were to be empowered to work telephone systems themselves at the cost of the borough rates, without the expense of a provisional order, if they received a licence from the Postmaster-General, and, if the National Telephone Company were reasonable, it was proposed, in fairness, it should have exactly the same wayleaves as the Municipality, if in the interests of the public service it would connect itself with the system of the Municipality.

After some discussion, in which Sir James Fergusson, Mr. Provand, Sir John Lubbock, Mr. Faithful Begg and others took part, the resolution was agreed to.

The Government Bill which was necessary in order to give effect to the proposals announced by Mr. Hanbury "to make further provision for the improvement of telephonic communication and otherwise with respect to telegraphs" was read a first time on Thursday, March 9th, 1899.

Mr. Hanbury's announcement, and the introduction of the Bill which followed it, caused some perturbation to the National Telephone Company, as might be expected, and occasioned no little excitement throughout the country amongst those Municipalities, local authorities, trade associations, chambers of commerce, and other institutions interested. Numerous meetings were held at which various resolutions were passed, some condemning the action of the Government in refraining from nationalising the telephones and purchasing the company's

system on equitable terms, others expressing approbation of the Government's intention to grant licences to Municipalities, and urging them to hasten passage of the Bill through the essential stages.

Much comment on the situation which had arisen, discussion of its pros and cons and criticism of the National Telephone Company, of the Government, and of Municipal ability to conduct telephone service and business satisfactorily, appeared in the Press. Objection was urged against the establishment of Municipal telephone undertakings by those who were opposed to Municipal trading, and some agitation took place with the intention of postponing the Bill, until the Joint Comittee appointed to consider the whole question of Municipal trading, which was much to the fore at that time, had issued its report. The Postmaster-General was badgered by Municipalities to grant licences, and assailed by deputations representing different bodies, and presenting different and sometimes diametrically opposed views.

In Manchester, a new telephone company, to be termed the New Mutual Telephone Company, sprang up, and at first had the support of the Manchester and other Corporations which approached the Postmaster-General with the object of securing for the new company a licence, but the Postmaster-General replied that it was quite impossible to grant a licence as matters then stood.

On Wednesday, May 3rd, Mr. Hanbury received a deputation from Chambers of Commerce, and other commercial bodies, who asked the Government to acquire the National Company's undertaking, and work it as a branch of the Post Office. Mr. Hanbury, replying to the representations put forward, said that there was really no strong and overwhelming reason why the local exchanges should be in the hands of the Government, and that as the local system, which accounted for 98 per cent. of the total telephone traffic, had not worked satisfactorily in private hands, it was proposed to put it in the hands of the local authorities. It was not in the public interest that the company should be able to give undue preferences; the existing system was insufficient; the question of wayleaves was fatal to the present system, and the Government proposals would overcome that difficulty; the Post Office was overburdened with work in every direction, and was considered to be incapable of taking on the additional burden. A

Treasury Minute on the subject would be published shortly, and he (Mr. Hanbury) would give further explanations when the second reading of the Telegraphs Bill came before the House.

The " Treasury Minute upon the proposals for the Development of the Telephone System in the United Kingdom," referred to by Mr. Hanbury, was dated May 8th, 1899; in it the proposals of the Postmaster-General to grant licences to certain local authorities to transact telephone business, and that the Post Office should itself open telephone exchanges in London, were agreed to in general terms. The opinion was expressed that the necessary sanction for borrowing on the security of the rates might be most conveniently given by a general Enabling Bill, such as had been introduced.

Generally the conditions pertaining to any licence were to be as follows :—

(1) The licence was to be of the same general character as that held by the National Telephone Company.

(2) Exchanges were to be connected to Post Offices, in order that the usual channels of communication provided by the Post Office might be utilised.

(3) Call offices were to be opened for public use.

(4) No terminal charge was to be levied on the trunk messages of other administrations.

(5) The plant was to be approved by the Postmaster-General.

(6) No preferential treatment was to be accorded.

(7) The charges were to be subject to the approval of the Postmaster-General.

(8) Licences were not to be assigned or sublet.

(9) Licences might be determined should exchanges not be established within a reasonable time, and if they were not efficiently worked.

(10) The royalties payable to the State were to be the same as those specified in the National Telephone Company's licence.

(11) All licences were to be terminable on December 31st, 1911.

(12) The plant was to be purchasable by the Postmaster-General on certain terms.

The final clause of the minute was as follows :—

" The right of the Post Office to establish telephone exchanges and to licence persons, companies and other bodies to establish such exchanges—a right explicitly reserved in every licence and

agreement with the National Telephone Company—will remain intact; and should Her Majesty's Government at any time see fit to exercise this right in a manner different from that indicated in this minute, neither the company nor any local authority will have any ground to complain of breach of contract, or want of good faith on the part of the Postmaster-General."

Mr. Hanbury moved the second reading of the Bill on Tuesday, June 21st, 1899. Sir John Lubbock moved that it be referred to a Select Committee. Mr. C. McArthur opposed the Bill, advocating nationalisation of the telephones, instancing that the objections to it were widespread, and urged that the National Telephone Company, who were the pioneers of the telephone in this country, should be dealt with justly. Mr. Faithful Begg said there was no way out of the muddle into which the Government had got except by a policy of purchase.

The second reading was agreed to, only after an appeal to the House, on Wednesday, June 22nd, 1899. When discussion of the Bill was resumed, it was referred to the Standing Committee on Trade.

A statement of the National Telephone Company's case was issued in June, in which they appealed for provision to be made in the Bill to secure to it :—

(1) Equal powers for running wires under and over ground which might be conferred upon any competitor.

(2) Equal conditions in all respects as to duration, terms and conditions of licence with those which might be applied to any competitor, and

(3) Protection in those cases where agreements had been entered into with local authorities, upon faith of which large sums of money had been spent in placing its wires underground.

The Bill was considered by the Standing Committee on Trade on Monday, July 3rd, and Thursday, July 6th, 1899, when it received certain amendments, and was thereafter ordered to be reported to the House.

On Monday, July 24th, the Bill was reintroduced in the House of Commons and was considered at length clause by clause. An attempt to adjourn the debate was defeated, and in the early hours of the following morning the Bill was ordered for third reading. Further debate was accorded it when read a third time on Monday, July 31st, 1899, but it was ultimately carried by 132 votes to 29.

On August 9th, 1899, the Bill received the Royal Assent.

Such radical changes were made to the Bill during the Committee stage, that it bore but a slight resemblance to the Bill originally presented to the House of Commons, and was described by *The Electrician* as a " remarkable piece of patchwork."

The principal provisions of the Telegraph Act, 1899, in its final form may be broadly stated as follow :—

1. The Treasury was authorised to issue out of the Consolidated Fund sums not exceeding £2,000,000 for the purpose of the Telegraphs Acts, 1863–1897, as might be required by the Postmaster-General.

2. Councils of borough or urban districts licensed by the Postmaster-General to provide a system of telephonic communication were empowered to defray the expenses incurred in exercising such powers out of the rates, and to borrow money in accordance with the Public Health Acts.

3. If an existing telephone company, already licensed and conducting business, agreed not to give favour or preference to any person, and that their charges should not vary from the maximum and minimum rates authorised by the Postmaster-General, it was to be a condition of the new licence that any powers acquired by agreement by the company with any local authority should continue for the duration of the new licence.

4. No person, or body, other than the recognised authority, was to be granted a licence in an exchange area already served by an existing company unless it was proved that the application for a licence had been approved by the local authority.

5. An existing company should not, without consent of the Postmaster-General, open an exchange in an area in which they had not, before the passing of the Act, established an effective exchange.

6. If an existing telephone company already licensed and conducting business, agreed not to give favour or preference to any person, and that their charges should not vary from the maximum and minimum rates authorised by the Postmaster-General, in an area in which a local authority, or new company, provided a competitive system, the tenure of licence of the company was to be coterminous with that of its competitor.

7. Should the licence of an existing company be extended for a period of not less than eight years, they were to be bound on

request, under conditions to be prescribed by the Postmaster-General, to afford facilities for intercommunication between their system and that of the new licensee, providing that the latter should afford similar facilities.

Under Section 3, sub-section 5, of the Telegraph Act, 1899, the Postmaster-General issued a Telegraph (Telephonic Intercommunication) Order, 1899, regarding intercommunication between competitive systems.

The Postmaster-General also issued, in anticipation of applications for telephone licences, a model form of telephone licence for local authorities, and a further model form of licence was also prepared for companies differing in some respects from that for local authorities. A reprint of the former appears in the pages of *The Electrician* for January 26th, 1900.

Following upon the Telegraph Act, 1899, there ensued a certain liveliness amongst numerous Municipalities, in considering the advisability of establishing local telephone systems of their own. Professional advice relative to the financial and technical considerations involved was in many cases sought and secured, and licences were applied for and granted. Particulars of the several Municipal telephone undertakings eventually inaugurated, and the fate which ultimately befell them are recorded in Chapter XIV.

Under the recommendations of the Treasury Minute dated May 8th, 1899, and the provisions of the Telegraph Act of 1899, the Post Office immediately took the requisite steps to institute telephone service in London, and also certain parts of the Provinces not hitherto effectively telephoned. The inauguration and development of the Post Office telephone service in London, and some of its work in the provinces receives treatment in Chapter XV.

One of the difficulties the Post Office encountered in inaugurating their telephone service in London was that of the provision of facilities for intercommunication between its prospective subscribers and the huge number of subscribers which, at that time, were already connected to the National Telephone Company's system. Intercommunication was a most desirable, if not absolutely essential requirement to the success of the Post Office London telephone service. Without it, the initial development of the Post Office system would undoubtedly be seriously hampered, inasmuch as each subscriber desiring communication with both systems would find it necessary to subscribe to both, and,

incidentally, a serious and unnecessary duplication of plant would result. It was therefore essential in the interests of the projected Post Office service that facilities for intercommunication with the National System should be forthcoming. Further information relative to the matter of intercommunication between the two systems, in which the London County Council was concerned is furnished in Chapter X.

There is little doubt that the question of intercommunication between subscribers connected to the National Telephone Company's system and those which the Post Office hoped to secure in London, a most important matter for the Post Office, as previously explained, exercised an important influence in the negotiations which culminated in the conclusion of an agreement between the Post Office and the company.

This agreement, dated November 18th, 1901, provided for purchase by the State of the company's plant and assets situate in the Metropolitan area as at December 31st, 1911, for free and full intercommunication between subscribers to the existing National and proposed Post Office systems, and for uniformity of rates. Particulars of the rates agreed upon are given in Table 22. The agreement also made provision that the Postmaster-General should furnish, and lease to the company on specified terms, certain underground wires in the London area, in order to assist in the development and improvement of the company's London system, and it included a "Specification and Rules as to Plant," to which future plant installed by the company was to conform.

The London County Council was much aggrieved at the conclusion of the agreement without their knowledge, and at the omission to invite them to confer as to the best course to adopt with regard to the telephone service in London. As early as 1897, the Council had prepared the following tariffs for London.

	Rate per annum.	
	Five years' agreement.	Yearly agreement.
First connection	£12	£15
Second and additional connections .	£10	£12
Private house connections . . .	£8	£10

The Council considered that one of the chief objects which they desired, namely, the setting up of effective competition, had not been attained in the agreement arrived at between the Post Office and the company, and on December 6th, 1901, a deputation from the Council waited upon the Postmaster-General, Lord Londonderry, when it was pointed out that, in the opinion of the Council, the proposed tariff was unreasonable, the toll system or message rate not being acceptable. The Postmaster-General was asked to reduce the unlimited rate to the figure which the Council had put before the company in 1894, viz., £12 per annum, and that the other charges proposed should be proportionately reduced. The hope was expressed that the agreement would not be carried through without Parliament having an opportunity of discussing it. The veto, which the Council possessed by the Act of 1892, over underground works of the National Telephone Company, was, in their opinion, now practically disposed of, and the deputation requested that no deprivation of their legal status should take place without some opportunity being afforded Parliament to reconsider and revise it.

Lord Londonderry, in reply, cited the reasons why competition in the usual trading sense was undesirable, and stated that the National Telephone Company, being a licensee of the Post Office, competition in the strict sense of the term was inappropriate and inadmissible. The company had agreed to intercommunication; an arrangement had been arrived at which might be fairly described as a system of competition, tempered by an element of co-operation, such as was necessary for the protection of public interests, and by which all the advantages of both systems were placed at the disposal of all subscribers to either. The document had been signed by himself, and would not come before Parliament.

The Highways Committee of the London County Council thereafter took counsel's opinion, as to whether the Postmaster-General was not acting in contravention of the Telegraph Act in not submitting the agreement with the National Telephone Company to Parliament.

The telephone charges announced by the Postmaster-General were subsequently considered at a conference of London local authorities, at which most of the local authorities within the London telephone area were represented. It was generally considered that the charges were excessive, that the telephone was

a necessity, and not a luxury, and that the agreement between the company and the Postmaster-General was illegal, and could not be sustained. Revision and reduction of charges were called for, and grave regret was registered that the Postmaster-General did not in any way consult the London local authorities before fixing the rates for telephone service.

On Monday, January 27th, 1902, the question of the agreement entered into between the Postmaster-General and the National Telephone Company was the subject of debate in the House of Commons. The debate arose out of Sir James Dimsdale's movement as an amendment, that the following addition be made to the Address :—

" But we humbly represent to your Majesty that it is essential that a complete inquiry should be made into the working and practical effect of the licences and agreements now being acted upon by the Treasury, the Post Office and the National Telephone Company, and the desirability of suspending any further transactions or negotiations between those Departments and the company with reference thereto, until such inquiry has been completed and its result considered by your Majesty's Government."

In moving the amendment, Sir James stated that the members of the recent conference at the Guildhall had deputed him to bring this matter before Parliament; it was generally held that the recommendations of the Select Committee on Telephones in August 1898 had not been given full effect to; the absence of competition, co-operation between the Post Office and the National Telephone Company, and the alleged high rates were the chief points presented.

The debate was a lengthy one, various arguments being advanced. Mr. Chamberlain and Mr. Hanbury were the principal speakers in support of the policy which had been followed by the Government.

The amendment was lost by a majority of 88 votes.

Thus in effect the agreement of November 18th, 1901, was approved by the House of Commons.

Early in 1904, rumours became current that negotiations were in progress between the Government and the National Telephone Company for the purchase of the latter company's telephone undertaking, and on March 24th, 1904, Lord Stanley, the Postmaster-General, made a statement in the House of Commons to

the effect that *pourparlers* were actually proceeding between the Post Office and the company, with a view to the Postmaster-General exercising the option to take possession of the company's system on December 31st, 1904, by giving six months' notice to that effect as from June 1904. Lord Stanley repeated a promise, previously made, that Parliament should have an opportunity of considering any proposed agreement with the company before it became binding.

On April 11th a conference of Municipal authorities owning and working telephones was held in London to consider what action should be taken with regard to the proposal of the Government to purchase the National Telephone Company's system. Representatives from Glasgow, Hull, Guernsey, Brighton and Swansea were present. The conference was of the opinion that local authorities should have an opportunity of working local telephones, and that the Government should be left to work and perfect the trunk system.

On Wednesday, May 18th, 1904, a conference on the London Telephone Service was held at the Guildhall, representatives from each of the 76 local authorities being present. The conference was called to consider what was supposed to be the proposal of the Government to purchase the interest of the National Telephone Company at once, instead of waiting, as had been expected, till the expiration of their licence in 1911.

The several local authorities were evidently not all in agreement as to the advisability of the Government effecting the proposed purchase forthwith, but nevertheless the following resolutions were carried :—

A. "That this conference is of opinion that it would be inexpedient for the Government to acquire the undertaking of the National Telephone Company on any other terms than those set out in the agreement between the Postmaster-General and the company dated November 18th, 1901."

B. "That this Conference is of opinion that before any agreement is entered into with the National Telephone Company for the purchase of their system within the London Telephone area, the terms of the proposed agreement should be submitted for the consideration of the Local Authorities within that area."

C. "That this conference again protests against the telephone tariff, being of the opinion that the charges for the use of a telephone in the London area should be materially reduced."

D. "That in the opinion of this conference the trunk line service is inadequate and unsatisfactory, and requires considerable improvement."

E. "That copies of the minutes of proceedings be forwarded to the Prime Minister, the Leader of the Opposition, the Secretary of State for Foreign Affairs, the Right Hon. Earl Spencer, the Postmaster-General, Metropolitan Members of Parliament, the various authorities in the London telephone area and to each of the delegates."

It was argued by certain delegates to the conference that it was no use having a cheap service without any regard to efficiency; it was also pointed out that there were absolutely no statistics to show that an unlimited service could be given for £10, a figure based upon an estimate made by the London County Council, and suggested as the flat rate rental which should be charged in London.

In answer to a question put in the House of Commons on Thursday, June 17th, 1904, the Postmaster-General, Lord Stanley, said :—

"After careful consideration I have arrived at the conclusion that it would not be in the public interest to exercise the compulsory powers of purchase reserved to the Postmaster-General, by clause 17 of the company's licence. I shall, therefore, not give notice to the company under that clause, and I am unable to say at present whether the negiotiations now in progress, with a view to a voluntary sale, will lead to a satisfactory result."

A second meeting of the conference of London Local Authorities was held on Tuesday, July 12th, 1904, when the Postmaster-General's reply to a communication enclosing copies of the resolutions passed at the last meeting was considered. Lord Stanley's reply was a lengthy one. In well veiled terms he as good as informed the Council that the purchase of the National Telephone Company's plant outside the Metropolitan area was no concern of theirs; he also stated that he had already promised that full opportunity would be given in Parliament for the consideration of any proposed agreement, that the calculations on which the third resolution of the conference was based had not been stated, that the unlimited service system of charging was unsuitable for a modern telephone exchange service, and owed its continuance to the force of custom and the demands of a limited number of large

users. The proper method of charge was described as that in which the payments of the subscribers were fixed in proportion to their user and that the message rate system offered fulfilled that requirement. The work of construction of a large number of trunk lines was in hand.

On Monday, November 7th, a deputation of representatives of Municipal Corporations owning and working telephone exchanges waited upon the Postmaster-General, to lay before him their views of the proposed acquisition of the National Telephone Company's undertaking, with the hope that some indication of policy which would make their course clearer, and strengthen their hands, would be given, but the Postmaster-General declined to express an opinion or say how the negotiations stood.

The expected agreement, dated February 2nd, 1905, was set forth in a memorandum dated February 14th, 1905. It was subject to ratification by the House of Commons and excited a good deal of comment in the general Press and business circles.

The Electrician, in its issue for February 24th, 1905, commented upon the agreement, and concluded its remarks with the following paragraph :—

" In view of the importance of telephony in commercial and social life, the delay in incorporating the telephone system, as an integral part of the telegraph system of the country, has been a grave mistake on the part of successive Governments. A few years ago, the acquisition of the National Telephone Company's undertaking would have been a comparatively simple matter. Whether the service was provided by a company or by the Government, however, nothing could prevent its growth, for the telephone has become almost a necessity in our everyday life. In addition to the money spent by the Post Office on the trunk lines and its London system, and the investments of Municipal authorities in their telephone ventures, the National Telephone Company has expended over nine millions of pounds on its system, and has now an annual turnover of over two millions (out of which one-tenth is paid to the Government as royalty). The transfer of such an enormous system as this is naturally no simple matter, and the Government has evidently realised this in allowing nearly seven years for its effective completion. The most serious blunder that was made was the ridiculous experiment in competitive telephony, doomed to failure from the outset, made with the passing of the Telegraph Act of 1899. At that time the Government should have made arrangements for taking over the National

Telephone Company's system in 1904, at which date it could have bought compulsorily under the company's 1884 licence, instead of encouraging Municipal authorities to waste their ratepayers' money in a spiteful and futile competition with existing telephone interests, and itself wasting the taxpayers' money in a competitive service in London, which had to be practically amalgamated with the company's service two years later."

In fulfilment of his promise that an opportunity should be given for consideration and discussion of the terms of the agreement, the Postmaster-General on two occasions moved in the House of Commons that a Select Committee be appointed to consider the agreement of February 2nd, 1905, between the Postmaster-General and the National Telephone Company, and to report whether it was desirable, in the public interest, that it should become binding, but on each occasion objection on some technical point was made. It was not therefore until Monday, May 22nd, 1905, that the Committee was appointed, the terms of reference being as follow :—

" To consider the agreement of February 2nd, 1905, between the Postmaster-General and the National Telephone Company, and to report as to any recommendations thereon, whether it is desirable in the public interest that the agreement should become binding, with or without modifications, and also whether the interests of the employees of the National Telephone Company have been duly considered."

Mr. Stuart Wortley was chairman of the Committee, which commenced its proceedings on May 30th, 1905. Evidence was taken from representatives of the Post Office, National Telephone Company, Municipal telephone undertakings, and the National Telephone Company's staff, and concluded on July 17th, 1905.

The Committee's report was issued in August, and recommended generally that in the public interest the House of Commons should not disapprove of the agreement; certain modifications to the agreement were suggested, however, and the Committee considered it should not become operative until a pledge had been given to the House that between the date of the report and January 1912 nothing should be done by the Government whereby the future ownership and managership of local telephone installations (as distinct from the ownership and managership of trunk lines) might be prejudiced, and that, unless by a vote of the House it

was otherwise determined, the Post Office should continue to grant licences to Municipalities, on terms not more onerous in respect of royalties than the terms of the standard telephone licence as revised in January 1902.

The debate in the House of Commons on the agreement took place on Wednesday, August 9th, 1905, when a resolution was moved to the effect that the sanction of the House should not be given to the proposed purchase agreement unless the various recommendations of the Select Committee were embodied therein. The Postmaster-General put forward his views at some length, and during the course of the debate stated his readiness to enter into negotiations with any of those Municipalities that might desire it for the absorption of their systems.

Mr. Austen Chamberlain congratulated Lord Stanley on his success in concluding the agreement, and said that a great mistake had been made when the telephone was first introduced, and since then the principal object of the Government had been to escape from the situation which had been created. It had been proved that competition did not secure a cheap and efficient service, and no Municipality which was not mad would start a new telephone system now to terminate in 1911. When we had emerged from the muddle of universal competition, and when the Postmaster-General was restored to his rights, a national telephone service could be established, which would be a credit to the country and a real assistance to its industry and commerce.

The House then divided, 110 voting for and 187 against the motion, and the agreement thus become ratified by a majority of 77 votes.

During the debate, surprise was expressed by several members as to the few municipalities which had taken advantage of the powers bestowed upon them, by the Act of 1899, to establish telephone systems.

Only five municipalities owned telephone systems, and at January 1st, 1905, there were only 17,770 telephone stations associated therewith, whereas the National Telephone Company, in the same towns served as many as 29,781 stations.

The ratification by Parliament of the agreement of February 2nd, 1905, between the Postmaster-General and the National Telephone Company constitutes practically the last legislative action respecting the telephone service of the United Kingdom.

Some further information relative to the operation of the " Specification and Rules as to Plant," comprising schedule 3 of the agreement, is given in other chapters of this volume, and in Chapter IX the last scenes in the troubled life of the National Telephone Company, enacted in the arbitration proceedings which arose out of the provisions of this important agreement, are briefly described.

CHAPTER XXII

MISCELLANY

As far as practicable endeavour has been made to segregate these chronicles into suitable parts forming convenient chapters each dealing with some distinct phase or section of telephone history. There are, however, certain portions of the subject which do not fall suitably into one or other of the several chapters already presented and which, therefore, will receive attention now. This, the final chapter, will consequently be subdivided as follows :—

1. Telephone Rates and Charges.
2. Telephone Development in America and the United Kingdom.
3. Alexander Graham Bell, 1847–1922.
4. The Post Office and the Period of the Great War.
5. Radio Telephony.
6. Conclusion.

1. *Telephone Rates and Charges*

Graham Bell's telephone was first put into commercial use in this country for the purpose of providing means of communication between two definitely fixed points, or, in other words, for private line service. Originally it was customary for sets of instruments to become the users' property by purchase outright, but later on they were supplied on rental terms which included the cost of maintenance.

Towards the end of 1877, Colonel Reynolds, who, at that time, was Professor Graham Bell's representative in London, issued a circular, reproduced in Appendix F, in which the following rates were quoted :—

	Purchase price.	Rental per annum.
For a set of instruments for short circuits .	£25	£5
For a set of instruments for long circuits .	£35	£10

A set of instruments consisted of a pair of telephones, that is, two Bell receivers, and a call bell, which comprised the equipment for one end only of a communication, and was similar to the telephone set illustrated in Fig. 3.

Special rates were offered for domestic purposes. The rental charge covered the cost of maintenance, and in either case the amounts quoted included all royalty charges. A pair of telephone sets for " long distances " could thus be purchased outright for £70 or rented for £20 per annum.

With the introduction of the exchange switching system towards the end of 1879, the Telephone Company ceased entirely from sale outright of their telephones and adopted charges on terms of rental only.

For exchange service a fixed annual rental, which included the maintenance of the plant and the cost of operating the service at the exchange, was adopted. The Bell Company charged £20 per annum. On what basis this figure was arrived at it is now impossible to say, but it is interesting to note that for many years £20 continued as the standard charge for telephone exchange service throughout the country.

In entering into competition with the Bell Company, the Edison Telephone Company of London, Ltd., adopted a rate of £12, which disappeared on the amalgamation of the two companies, after a short period of competition, which receives fuller mention in Chapter II. The Edison Company's charge for service to the provincial exchanges which it established was £12 also. The United Telephone Company, formed on the amalgamation of the two original companies, retained the Bell Company's rate of £20. A little later another competitor appeared in the London and Globe Telephone and Maintenance Company, Ltd., who charged £10 per annum, a rate which again disappeared in favour of the £20 rate, upon the acquisition of the latter named company by the United Company, in the circumstances related in Chapter III.

Various rates were established by the several telephone administrations which entered the telephone field in the provinces, most of which are given below :—

Name of Telephone Company.	Locality.	Annual rental.
Tasker Sons and Co.	Sheffield.	£7
Midland Telephone Co.	Birmingham.	£20
Sharples and Co.	Preston, Lancs.	£6 afterwards raised to £8
Moseley and Sons	Manchester.	£12 *
D. and G. Graham	Glasgow.	£12 afterwards increased to £15
Dundee and District Telephone Co.	Dundee.	£10 afterwards reduced to £5 10s.
Blakey and Emmott	Halifax.	£12
Scottish Telephonic Exchange, Ltd.	Edinburgh.	£—
British Post Office	Various.	£8
United Telephone Company and Associated Companies	Various.	£20

* Not brought into operation.

These rates are not strictly comparable owing to the slightly varying conditions in which they were applied.

At a later date, the Mutual Telephone Company of Manchester adopted a rate of £6. The New Telephone Company was promoted principally for the purpose of competing with the National Telephone Company in London; they decided upon a tariff of £12 12s. per annum for the first 5,000 subscribers secured and £14 per annum for subsequent applicants, but, owing to the circumstances related in Chapter X, these rates did not come into operation.

All the above-mentioned rates represented a fixed annual charge and were in no way graduated in relation to the extent the subscriber made use of the service.

It will be observed that the rates varied in amount between such wide limits as £5 10s. and £20, an indication perhaps that telephone rates were not understood and that experience was wanting on which suitable rates might be based. The com-

paratively high rate charged universally by the United Telephone Company is, however, conspicuous.

Some of the rates quoted quickly disappeared, owing to the acquisition by the United Co., or its associated companies, of the firms who had instituted them, and with some exceptions a rate of £20 became general throughout the country. It was not until May 1st, 1890, that any radical change was made in the rates charged, when in Manchester and Liverpool and other towns in Lancashire and Cheshire the annual charge was reduced from £20 to £15. This reduction was quickly followed on January 1st, 1891, by another, when a general tariff of £10 was adopted, applicable to the whole country, with the exception of the Metropolis and one or two other places of less importance.

If, at the beginning of the telephone business, it had been realised that the charge for service should have been based upon the message as the unit instead of on the telephone line or circuit, a vast amount of controversy and trouble of various kinds would have been avoided.

It appears to be perfectly reasonable, however, that, at the commencement, a flat rate should have been adopted, inasmuch as such a method of charging for telephone service fitted the conditions of the times. The number of subscribers was small and so indeed was the amount of traffic which they passed over their circuits. The capital value of the plant was not great, and the use made of the different lines did not vary to the same extent as when the telephone service came to be more generally used.

The rates charged for exchange telephone service have been an endless source of discussion ever since the telephone service was inaugurated. The reader of these chronicles will, no doubt, be well acquainted with the contentious subject of telephone rates and the arguments which have been advanced for retention of the flat rate which was in vogue for so long a period, and also for its abolition in favour of a rate which took account of the extent to which the service was used. Students of latter-day telephone economics have invariably been in favour of, and have advanced sound arguments for, the adoption of a system of charging for exchange service based upon the extent to which that service was utilised as represented by the number of calls originated.

For private line service, the matter is somewhat different. A line of definite length between two fixed points is affected to a

comparatively small degree only by the amount of use made of it. Exchange service, on the other hand, involves about the same small wear and tear of the subscriber's apparatus as in the case of an instrument used for private purposes, but, in addition, involves a wear and tear upon the exchange switching apparatus and, what is of much greater moment, an expenditure in the cost of operation entirely absent with a private line. Each call costs the administration a definite amount for its operation and consequently, so far as operating is concerned, the cost incurred is almost directly proportional to the number of calls made. It has been argued, therefore, that the proper basis of charge for telephone service should as nearly as possible correspond with the charges incurred in supplying service, which are made up as follows :—

(*a*) Interest on capital investment involved.
(*b*) Depreciation of plant concerned.
(*c*) Maintenance costs of plant concerned.
(*d*) Cost of operation.
(*e*) Profit, if any, adjudged according to the policy of the administration.

(*a*), (*b*), (*c*) and (*e*) are practically constant for each subscriber, but (*d*), the cost of operation, varies in direct proportion to the number of calls passed by the user.

Exchange service stands therefore entirely apart from private line service in so far as the cost incurred by the telephone administration is concerned, and the arguments advanced for the imposition of a charge, which is a measure of the service rendered, undoubtedly appears irrefutable.

A flat rate based on the distance of the subscriber's premises from the exchange, and therefore roughly proportional to the capital cost, was universally adopted in the early history of the telephone service, and continued in force for some years, but as the service developed and the economic aspect of telephony began to be more closely studied, it came to be appreciated that a rate which permitted unlimited use of the service was not an equitable arrangement. It was particularly unsuitable, and in fact excessive, for the small telephone user, who had to pay exactly the same annual rental as the subscriber whose telephone was in constant use throughout the day. Many people refrained from becoming subscribers on account of the high charge, and the use of the

telephone was largely confined to large and progressive firms and business houses, and to the well-to-do at their private residences. Manufacturing costs of telephone apparatus and materials were at this time on the down grade, while, as the service became more popular, the operating costs were rising, consequently the cost of operating was a factor which was exerting a greater influence on the working costs. It was therefore considered that a lower rate fixed in relation to the amount of use made of the service would bring the telephone within the reach of a larger section of the public, would result in popularising and developing the service and would be financially sound. Unfortunately, the application of a rate apportioned on this basis, while cheapening the service for the small user and therefore encouraging development generally, also had the effect of increasing considerably the cost to the larger users, who, being subscribers already, were naturally much averse to the introduction of a system of rates which would involve them in higher charges for telephone service than they had been wont to meet. British Chambers of Commerce have persistently opposed the universal adoption of a measured system of charging.

The abolition of the "flat" rate and the substitution of a method of charging based on the number of originating calls were first publicly broached in this country by Mr. W. E. L. Gaine, the general manager of the National Telephone Company, at Sheffield, on May 9th, 1892. The proposal was, however, received with such evident hostility, principally by the large and influential telephone users, that no progress was made and the matter was dropped.

Large users have overlooked or neglected to take into account the communal advantages which undoubtedly would have accrued from the universal application of the measured rate and the additional channels of communication opened up by a large increase in the number of subscribers. The argument that the cost of operating their service was actually greater than the price paid for the facilities rendered, the difference being made up by the flat rate small user who, in consequence, paid a higher rental than was equitable, had no weight with them.

The first rates quoted in America made distinction between business and social service, and thus the principle of the measured rate was in part recognised. From the commencement of telephonic intercommunication in America, both the flat and measured

basis of charging were practised, but by 1882 the companies employing the measured rate of charge had practically all reverted to the flat rate, which continued in vogue until 1894. The measured rate was then introduced into New York and other places, and although its adoption was optional to the subscriber, by 1907 but a few hundred flat rate subscribers remained in the city mentioned. The introduction of the measured rate in the United States undoubtedly contributed in a large measure to the huge development which set in shortly afterwards and to the popularity the telephone service now enjoys in that country.

The British Public, or at least a small but nevertheless influential section of it, besides opposing every endeavour made towards the abolition of the flat rate, has perhaps been loudest in its condemnation of the British telephone administrations, be they private or public, in the alleged failure to develop the telephone in this country to an extent comparable with what has been accomplished in other countries, in particular the United States of America. The fact that the remarkable development in America was largely due to the suppression of the flat rate and the introduction of the measured rate system of charging appears to have been lost sight of by the adherents of the flat rate, and it is therefore not unreasonable to place the responsibility for the low telephone development experienced in this country upon these members of the public who have persistently and selfishly clung to the flat rate and done their utmost to prevent the universal adoption of the measured rate in its place.

The intention of those Municipalities who embarked upon telephone enterprise was to establish telephone service at a price to the subscriber considerably below that charged by the National Telephone Company, who at that time held a monopoly. One of the reasons which has been given for the want of success which attended the efforts of Municipalities was that the rates charged were too low to permit of financial success. Particulars of most of the very similar rates adopted by the several Municipalities are given in Chapter XIV.

In 1900 the "message rate" was introduced in the provinces both by the Post Office and by the National Telephone Company. The message rate consisted of a comparatively small annual rental with the addition of a charge for each effective call against the subscriber originating it; incoming calls were not charged for.

The annual rental for this rate was originally fixed at £3, but this was eventually found to be too modest a figure, and in 1907 a measured rate was introduced. The measured rate differed from the message rate only in that the annual rental for the former included payment for a certain number of calls and that subscribers were permitted to purchase on a graduated scale of payment additional groups or blocks of calls.

The measured rate adopted by the Post Office was £5, which included 500 calls, additional calls being purchasable as follows :—

No. of calls.	*Price per* 100.
501–1000	8*s.*
1001–2000	6*s.*
2001–4600	4*s.*

In areas where the predominating service was that of the National Telephone Company, the annual charge was £6, also including 500 calls, additional calls being charged for as below :—

No. of calls.	*Price per* 100.
501–1300	7*s.* 6*d.*
1301–4600	4*s.* 0*d.*

In each case calls beyond the limit of 4,600 were charged at 1*d.* per call. These rates were introduced for new subscribers in place of the flat rate, no further agreements for flat rate service being entered into except for private residences. Existing subscribers were permitted to retain their old rates if desired, but every inducement was offered them to change to the new ones.

This was the first real step made towards the total abolition of the flat rate.

An objection urged against the measured rate method of charging is that undue preference is still given to the large user, who purchases his calls at a lower rate than the small user, in spite of the fact that, call for call, the cost to the administration is the same.

The agreement entered into between the National Telephone Company and the Postmaster-General in 1901 fixed the rates which were to be charged in London by each administration, and provided for an unlimited service at £17 per annum and £14 for

second and additional lines. A message rate service was also introduced at £5 per annum for subscribers connected to exchanges within the London County boundary and £4 for subscribers to exhanges in outer London, with an additional charge of 1*d*. per outgoing call. An additional 1*d*. was charged for each call between exchanges situated respectively within the Inner and Outer areas and between an exchange in the Outer area and any other exchange in the London area. These rates continued in force until and after the transfer of the National Telephone Company's telephone undertaking to the State on January 1st, 1912. (See Table 22.)

It was confidently expected that, very soon after the acquisition of the National Telephone Company's system by the State, the telephone tariffs of the whole of the country would be revised and a new tariff introduced which would at once sweep away the ambiguities which existed; some anticipated a substantial reduction in telephone charges. There were in existence many obsolete rates established by the National Company and by Municipalities for competitive purposes. In telephone circles the cancellation of the inequitable flat rate in favour of the measured rate was regarded as a foregone conclusion. The intervention of the war and the extreme conditions it created put a stop, however, to the project and the introduction of revised telephone rates as a permanency was therefore postponed. It was not until the increased cost of administering the telephone service demanded that an increase in the charges should be made that anything was done, and increases in the existing tariffs generally in force were therefore imposed as a temporary expedient.

In the financial year 1914–15 there was a loss on the working of the telephone system of £111,018, which increased to £118,177 in 1915–16, nearly the whole of which loss was attributable to the trunk system.

On October 1st, 1915, the whole of the obsolete rates were abolished excepting the provincial flat rate. In London the rate for unlimited exchange service was raised from £17 to £20 for the first line and from £14 to £17 for additional lines, and in the Provinces the unlimited rate was increased from £10 to £12 for the first line and from £8 10*s*. to £10 for additional lines. Trunk charges were increased by a uniform addition of one-third, and

in the year 1916-1917 the result of the working of the telephone system was converted into a profit of £201,729.

On September 6th, 1915, for all new telephone services a "surcharge" was introduced, the minimum payment being fixed at £4, with a view to limit applications to persons and firms urgently in need of the facility, and reduce the work of the under-staffed engineering department. The surcharge had the desired effect and during the seven months ended March 31st, 1916, the number of applications was reduced by about 50 per cent. and receipts amounting to £45,000 were produced.

In spite of the general increase in price of all commodities which had been imposed in consequence of the war and the justification which existed for increased telephone charges, a good deal of opposition in business circles was aroused and the first warnings of still another agitation against the administration of the telephone service were manifested.

Soon after the war terminated, that is, on May 7th, 1919, the Postmaster-General, the Right Hon. Albert H. Illingworth, appointed a Departmental Committee "to consider and report what alterations in the existing telephone tariffs are expedient with a special reference to the necessity of placing the telephone service on a remunerative basis."

This Committee's task was no light one, having in view the conditions which obtained at the time. Not only were costs of all descriptions unduly inflated as a result of the war, but the unsettled conditions which existed made it impossible to foresee with any tolerable degree of accuracy what the trend of things would be in the future. The report issued by this Committee on June 30th, 1920, was a veritable text-book on the subject of telephone rates and dealt with the question very fully. Generally stated, the findings of the Committee were that the unlimited or flat rate was inequitable and that the rates should, as far as possible, be fixed in proportion to the cost of giving each class of subscriber the service required, and that the measured rate was open to the objection of undue preference though in a less degree than the flat rate. The message rate, in which a fixed annual charge for the installation and a uniform charge for each effective call were made, was considered to be the most equitable and convenient and was recommended for adoption as the basis of the general tariff. It was pointed out that the cost of supplying

service to private residences and to business premises was the same and that the same rates should therefore apply. The report showed that the annual installation rental should be £8 10s. in London, £8 in Birmingham, Glasgow, Liverpool and Manchester and £7 10s. elsewhere, and that the uniform message fee should be 1½d. per call. For further and fuller details of the charges recommended reference should be made to the Committee's report.

On June 21st, 1920, it was ordered " that a Select Committee be appointed to examine the present charges made to the public for the use of the telephone service and to report in what respects these charges require revision in order to place the service on a remunerative basis." The report of the Departmental Committee, dated June 30th, 1920, which has already been referred to, formed the basis of inquiry of the Select Committee. Generally, the Departmental Committee's report was followed and its recommendations were concurred in. The principal findings of the Select Committee may briefly be stated as follows :—

(1) There was no reason why the State should supply telephone service to large users considerably under cost price and discontinuance of the flat rate was recommended.

(2) The measured rate was also to be discontinued.

(3) Agreement with the Post Office was expressed in recommending the message rate as the only equitable system of payment for service rendered.

(4) The tariffs proposed by the Departmental Committee were considered justifiable and were recommended for adoption.

(5) It was considered that the question of charges should be reconsidered within the next few years by a Parliamentary Committee.

On April 1st, 1921, the recommendations of the Departmental Committee, supported by the Select Committee, were brought into force without substantial modification, but not before the general outcry which preceded their introduction had resulted in the appointment of a Select Committee to inquire into the organisation and administration of the telephone service and the method of making charges. The deliberations and report of this Committee are referred to elsewhere.

In spite of the antagonism which the newly-imposed rates aroused, they continued in force until July 1st, 1922, when a

reduction amounting approximately to 20 per cent. was made in the installation charge for private residences only and the message charge was subject to a general reduction from $1\frac{1}{2}d.$ to $1\frac{1}{4}d.$

At the same time modified charges for long distance conversations were introduced.

On July 1st, 1924, a further revision in telephone rates was made; the message fee was changed from $1\frac{1}{4}d.$ to $1d.$, and certain trunk charges for distances up to 50 miles were reduced approximately by 10 per cent.

2. *Telephone Development in America and the United Kingdom*

The preparation of this volume has been undertaken more especially for the purpose of recording the commercial and technical progress of the telephone in the United Kingdom and therefore mention has been made of the work and inventions of American engineers only where, in the interests of a connected narrative, such a course has been deemed desirable. The development technically of the telephone in this country is, however, inextricably bound up with that of the United States and therefore many processes, appliances and devices which have been employed in connection with the different branches of telephonic science are identical in the two countries.

The telephone being invented and first exploited in America, it is not surprising perhaps that America has been foremost in its adaptation to the social, commercial and industrial life of the community. Consequent upon the earlier establishment and more rapid growth of telephone service in the United States than in any other country in the world, the numerous technical and economic problems produced by expansion of the art were confronted in America at an earlier date than the similar problems in this country. From the very first, therefore, the superior commercial development of the telephone in America created a much wider field for the exercise of inventive genius than has been presented at any time in this country. Problems arose, which in the interests of humanity it was necessary should be solved, and prospect of their solution lent encouragement to the application of time, labour and sums of money thereto. Consequently, when British telephone engineers were faced with similar problems and difficulties, the way was already open for the needs

of the moment to be immediately met. In many cases, therefore, it has been necessary in these pages to treat of processes and apparatus devised and developed in the United States.

In view of the important part which American products have played in connection with the telephone service of the United Kingdom, a few words relative to the growth of the commercial telephone organisation in America may not be irrelevant.

By January 1st, 1877, less than twelve months after Graham Bell had been granted his original telephone patent, there were more than 2,500 telephones in use in the United States. These had been supplied by Professor Bell and his earlier partners. The first commercial organisation for the exploitation of the telephone in America was the Bell Telephone Association, consisting of Dr. Bell, Gardiner S. Hubbard (Bell's father-in-law), Thomas Sanders, a leather manufacturer who had largely financed Dr. Bell, and Thomas A. Watson, who had assisted in the early experiments and constructed the first telephones.

In 1878 two companies were formed, the New England Telephone Company and the Bell Telephone Company, the operations of the former being confined to the New England States and the Bell Company covering the rest of the country. The Bell Telephone Association disappeared at this time. In the following year the two companies named were combined as the National Bell Telephone Company, which, in 1880, was acquired by a newly-formed company under the title, the American Bell Telephone Company.

As related in Chapter I, the first telephones were manufactured by Thomas A. Watson in the electrical workshops of Charles Williams of Boston. This source of supply quickly becoming inadequate, licences were arranged with other concerns for the manufacture of telephone apparatus on a large scale. The Western Electric Manufacturing Company had been formed as early as 1872 out of a partnership contracted three years earlier between Elisha Gray and Enos M. Barton.

In 1881 all these companies were consolidated as the Western Electric Company, the American Bell Telephone Company retaining control, and the manufacturing section of the American telephone business was thus founded.

The Western Electric Company gradually became the manufacturers of almost the whole of the apparatus required in the

Bell System and they also supplied for some time the greater part of the needs of the world.

In 1899 the American Bell Telephone Company was merged with the American Telephone and Telegraph Company, formed in 1885 to organise long distance communications. The closest co-operation was instituted between the operative or executive departments of this huge administration and the manufacturing side (the Western Electric Company), and this feature has no doubt largely contributed to the success of the undertaking.

Subsequently, numerous independent companies became associated with the American Telephone and Telegraph Company and the whole now constitutes that which is known as the Bell System. At the beginning of 1922 there were approximately 10,300 separate telephone companies in the United States, of which 26 were associated companies of the Bell System and 9264 independent companies whose exchanges were connected with the Bell System. There was also a large number of rural lines and associations not constituted as companies, but worked mainly on a mutual or co-operative basis, and of these some 26,000 were connected with the Bell System.

The American Telephone and Telegraph Company is thus the parent company which, besides giving a centralised administrative service to its associated companies, connects them together by means of its long-distance lines. It also maintains for the whole Bell System the research, investigation, experimental and manufacturing departments, the latter in the form of the Western Electric Company, and it also supervises the accounting and financial operations.

The telephone business in America thus grew to be a huge undertaking long before it became a concern of any magnitude in this country, and therefore it merited an organisation and expenditure in research and development which it has been denied here. It was unaffected by Government licence, and instead of meeting with cold disinterestedness or even opposition on the part of Municipal and other public authorities, it appears to have been accepted with a generous appreciation of its utility and possibilities which was never accorded in the United Kingdom.

It is difficult for those who have not actually visited the United States and experienced for themselves the generous and universal

use which is made of the telephone there to appreciate the extent to which its development has been carried, nor is it easy to convey an adequate impression of the different aspect in which the

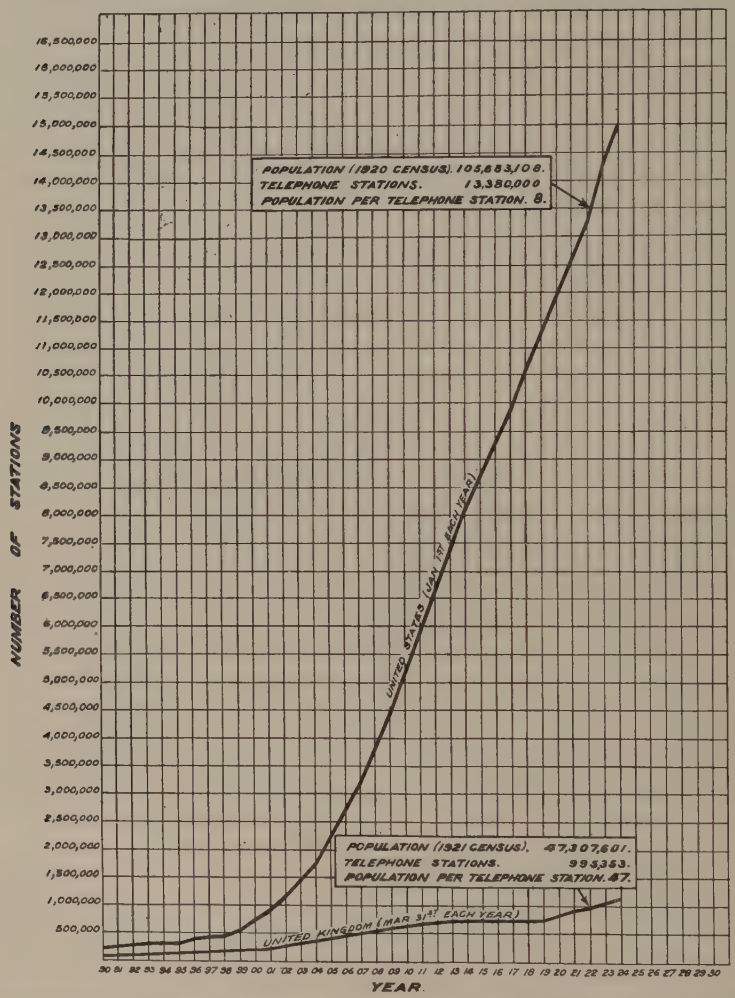

NUMBER OF STATIONS
YEAR
POPULATION (1920 CENSUS). 105,683,108.
TELEPHONE STATIONS. 13,380,000
POPULATION PER TELEPHONE STATION. 8.
UNITED STATES (JAN 1ST EACH YEAR)
POPULATION (1921 CENSUS). 47,307,601.
TELEPHONE STATIONS. 995,353.
POPULATION PER TELEPHONE STATION. 47.
UNITED KINGDOM (MAR 31ST EACH YEAR)

FIG. 182.—Graphical Comparison of Telephone Development in the United Kingdom and the United States.

telephone is viewed in America from that in this country. The development of the telephone in the United States since about 1900 has been little short of phenomenal, until at the present time there is one telephone station to less than eight of the population, which totals over 105 millions. In the United Kingdom, with a

population of about 47 millions, no more than one telephone per thirty-eight of the population has ever existed.

The actual development in telephone stations in the United

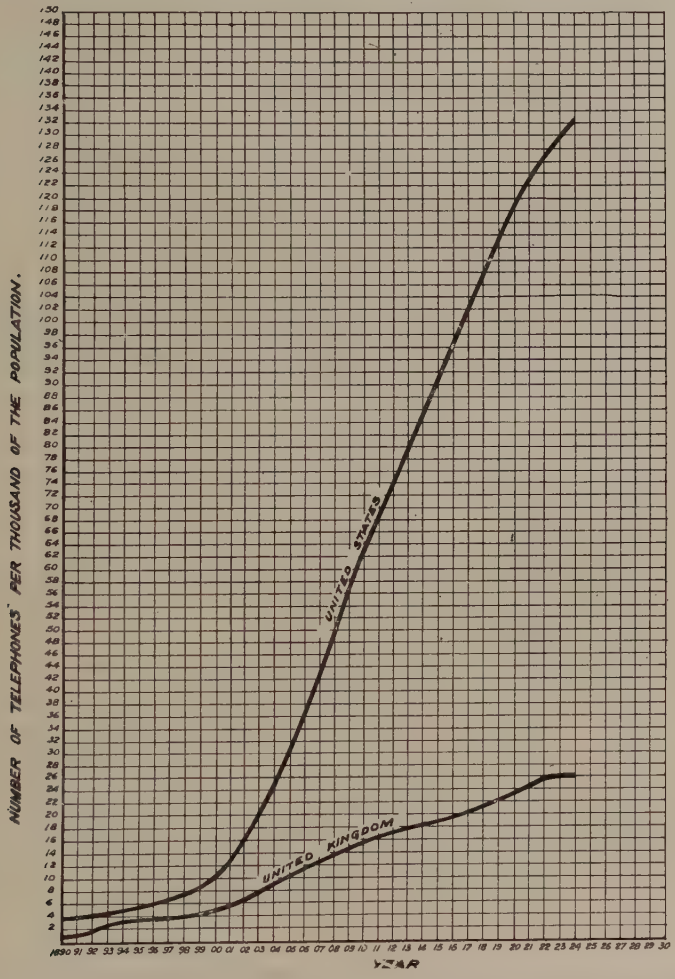


FIG. 183.—Graphical Comparison of the number of Telephones per thousand of the population in the United States and the United Kingdom.

States and in the United Kingdom is compared graphically in Fig. 182. The two curves there shown take no account, however, of the relative sizes of the population of the two countries, and fair comparison cannot therefore be made from their examination. The two further curves in Fig. 183 show the increase in the number

of telephones per thousand of the population of the two countries from 1890 to 1924, and it will be observed that in America the number of telephones per thousand individuals was at January 1st, 1924, as high as 132 and that at about the same date in this country the relative figure was 26.

The generous development of the telephone in America has frequently been compared with that of the United Kingdom and always to the disparagement of the latter. The subject has been greatly discussed and various views have been advanced in explanation of the difference. The conditions in America are very different from what they are in this country. The topographies of the two countries are entirely dissimilar, as also the habits and temperament of their respective peoples. The climatic conditions vary and the costs of labour and of machinery are not comparable. Reasons for the proportionately higher telephone development of the United States as compared with that of this country are probably to be found in these differences, coupled, perhaps, with the adoption in America of a bold progressive policy, which through lack of financial backing, absence of encouragement and the prevalence of conservative ideas, it was impracticable to adopt in the United Kingdom. There is also the fact that the telegraph service in the United States was never developed so highly as in this country.

The Americans have, no doubt, outstripped the British in developing the telephone service, but it must not be imagined that natives of these islands have made no contributions of importance to the science of telephony. On the contrary, apart from modern contributions, which are not inconsiderable, the reverse is the case, as a perusal of some of the chapters of this book and an examination of the Patent Office records will show.

Apparently through inadequate measures being taken in this country for their technical and commercial development, numerous valuable inventions and devices of British origin were allowed to sleep in the archives of the British Patent Office, until they were eventually taken up in America and carried to a successful and profitable issue.

In course of the inquiry and investigation which have been conducted in collecting and arranging the information contained in these pages, the author has been particularly impressed with

the amount and importance of the pioneer work carried out by British engineers and inventors.

Alexander Graham Bell, the inventor of the telephone, was by birth a native of Edinburgh, on his mother's side of English and on his father's side of Scotch blood. He had been resident in America for the brief period of five years when his discovery was made.

Professor Hughes, who, in 1878, produced the carbon pencil microphone, the forerunner of all the carbon transmitters which followed, was a Londoner.

The first form of granular carbon transmitter was invented by Henry Hunnings, a Yorkshire clergyman, and from his invention has been derived the present-day transmitter in use throughout the whole world. Hunnings' invention was improved by Marr and Moseley, of Manchester, and others, but was eventually perfected abroad.

William Young and Archibald McNair, of Paisley, patented in 1845 a method for applying to a cable in continuous form a sheath of lead, which idea apparently lay dormant until revived first in Switzerland and later was applied in the factory of the Western Electric Company in America for sheathing the cables they manufactured.

The Patterson cable commonly used in America for telephone purposes in the 'eighties was, with one comparatively minor exception, designed and manufactured in America in a manner precisely similar to that devised and patented in this country by W. A. Marshall, of Canonbury, as early as 1869.

The loading coil produced by Professor M. I. Pupin, of America, in 1899, was the outcome of the mathematical expressions of Oliver Heaviside, an Englishman, advanced twelve years previously in this country.

The two factors which undoubtedly have done more than any others to forward the progress of practical commercial telephony are the dry core cable and the common battery system, and it is generally understood that both originated and were developed exclusively in America. To a certain extent only is this true, for, whether or not they were invented and developed in America quite independently of the previous work done in this country, nevertheless it is clear that a cable system, virtually dry core, and a common battery system were devised and

employed in this country before America. In Chapter VIII of this work it is shown that W. F. Cook, of English telegraph fame, devised and employed a system of cable in 1843 which to all intents and purposes was dry core but which, unfortunately, for want of proper development was allowed to lapse. In America in 1900 the idea was carried through to success.

In 1882, George L. Anders, an American, who previous to that date was electrician to the American Bell Telephone Company, invented, patented, and employed for the London and Globe Telephone and Maintenance Company a system of telephone working described in Chapter III which was the present day common battery system in embryo.

Mr. J. E. Kingsbury in his book, " The Telephone and Telephone Exchanges," of which frequent mention has been made, has told very fully the story of the development of the different branches of technical telephony in the United States. The student of his work will, no doubt, be impressed more particularly by the admirable way in which the particular faculties with which the Americans seem specially gifted were exercised in the co-ordination of individual effort and ability, in organising capacity and business enterprise, coupled necessarily, of course, with a high degree of scientific skill, and which were brought to bear in guiding to a successful issue the solution of the problems encountered.

Mr. Kingsbury makes frequent reference to the work which was done in America under the auspices of the National Telephone Exchange Association, an association of telephone companies in the United States who were licensees under the Bell patents. In perusing Mr. Kingsbury's accounts of some of the operations of this association one cannot but be struck with the admirable work which was done, and with the deliberate and business-like manner in which problems of the moment were attacked and satisfactorily and expeditiously solved. Commenting upon the question of the development of switching systems in respect of the period 1890–1892, on page 371 of his book, Mr. Kingsbury says :—

" Skilled men were limited in number and they were kept very busy in supplying the needs of the moment. There were keen students of individual problems, such as Van Rysselberg in Belgium and men who were adopting a scientific attitude towards the exchange system as a whole like Wietlesbach in Switzerland, but

only in the United States were there organised efforts at advances and improvements in exchange methods."

A prominent feature of the methods which seem to have been consistently practised in America and which appears particularly striking and worthy of special note was the decision by a body of competent men upon a policy based on sound argument, definitely shaped and strenuously pursued, without deviation from the main purpose, in order to attain the end desired. Referring to the deliberations of a committee appointed to consider, amongst other things, the practicability of concentrating all battery power at the Central Exchange, Mr. Kingsbury says, on page 377 of his treatise :—

" After discussing the subject fully the committee voted an emphatic recommendation that provision should be made for supplying current to sub-station transmitters in some other manner than by means of primary batteries at the subscribers' stations."

The object to be attained was thus definitely agreed upon and it was ultimately accomplished by the production of the common battery system, now the universal manual system of telephone switching throughout the world.

It seems evident that the Briton was not deficient in ideas and inventive genius, but lacked the means to develop them or the financial support which was essential in order to perfect them and bring them to practical utility. Whether in America the ideas which have been mentioned were conceived quite independently, without knowledge of the work of previous inventors in this country, cannot now be readily determined, but it seems probable that the pioneer work done in this country was known and made use of there. In the discernment of a promising invention or idea and in the exercise of enterprise and organising ability in its development and exploitation, the Americans seem to display particular activity. Lack of enterprise in the development of new ideas and inventions in this country in the early days of telephony was the subject of comment by Mr. G. L. Addenbrooke, during a discussion which followed a paper read before the Institution of Electrical Engineers, by Mr. J. E. Kingsbury, on January 24th, 1895, entitled " The Origin and Development of

the Telephone Switchboard." A report of Mr. Addenbrooke's remarks upon that occasion was as follows :—

"He had made one or two attempts himself to design boards of one sort or another, but there is no doubt English telephonists were greatly handicapped in comparison with their American brethren. Unfortunately in the early days of telephony, the telephone company seemed to consider that so far as the staff were concerned, the finality of things had come, and if any improvements were to be made, they must start from outside. There was no want of ability on the part of the servants of the company, but the management did not encourage any work of an ingenious kind. It was desirable that people should know how differently the Western Electric Company had acted in this matter. He himself was in America about four years ago, and having an introduction to the president of the company from Mr. Kingsbury, the former showed him over the works of the company, and explained how they worked. They had a special department dealing with inventions, and that department was in communication, as far as possible, with telephone companies all over the country, and received information and complaints from them. It was the duty of this department to go through the mass of complaints and suggestions and to see how far those suggestions could be put into practical form; there was no doubt that had been the most successful policy. At the present day, when they looked back at all that had been done in the way of telephone switchboards, they might almost say that the progress of telephony had rested with the Western Electric Company and with the affiliated companies, whose various superintendents, with their knowledge of practical working, had been able to make suggestions from time to time. It used to be a great sorrow to him that English electricians had not the chance that Americans had. Probably matters were altered now. At any rate, British people ought to take a leaf out of the book of the Western Electric Company in that matter."

In 1891 the Western Electric Company was organised in a manner which undoubtedly placed it in a position to lead the way, as it has done, in telephone engineering.

In this country an endeavour was made early in 1889 to institute an annual conference of telephone engineers. It was advocated by Mr. C. B. Clay (at that time general manager of the Northern District Telephone Company) in the correspondence columns of *The Telephone* for February 1889. The matter was taken up vigorously by that journal, and eventually it was arranged that a convention should be held on July 11th, 12th and 13th, 1889.

The project came to nothing, however, and an announcement was issued to the effect that, owing to pressure of work imposed upon the officials of the telephone companies in England, through the amalgamation of the principal companies, the proposed convention was to be postponed until the following year. It seems unfortunate that in this country no organised means existed whereby individual ideas and effort might have been collected, precipitated and filtered, and that as a consequence such talent as existed was not utilised to the advantage of the home country.

3. *Alexander Graham Bell*, 1847–1922

When the author's present work was nearing completion news was published of the death of Dr. Alexander Graham Bell, the great inventor by whose efforts telephone communication was made possible. It is therefore fitting that some further mention should be made of the originator of the means of communication which is the subject of this volume in so far as its employment in the United Kingdom is concerned.

Dr. Alexander Graham Bell, LL.D., Ph.D., D.Sc., M.D., was born on March 3rd, 1847, in Edinburgh. On his father's side he was of Scotch blood and on his mother's English. His father, Alexander Melville Bell, a well-known citizen of Edinburgh, was an elecutionist who devised a system of symbols, based upon the action of the vocal organs, for teaching correct speaking, termed by him " visible speech." Graham Bell's grandfather, Alexander Bell, was also an elocutionist and the training he received from, and his association with, both father and grandfather undoubtedly were factors of importance in the special studies, investigations and experiments which he afterwards undertook. He was educated at the Royal High School, Edinburgh University, and University College, London.

Tuberculosis accounted for the death of two of Graham Bell's brothers, and, as he too was threatened with the same disease, in 1870 his father removed to Canada, in the hope that the change of climate would arrest the complaint, and eventually effect a complete cure. He settled in Brantford, Ontario, some twenty-four miles from Toronto. Many of his experiments in the development of his invention were carried out at Brantford, and consequently that place became known as the " telephone city."

In 1871 Graham Bell went to Boston in place of his father

to take up an appointment in the education of the deaf, and he soon became established also as a teacher of elocution. He became professor of the mechanics of speech at Boston University and continued to give private lessons in elocution. He developed methods for teaching the deaf and dumb and applied the system devised by his father to that end.

Graham Bell, as a boy, had become interested in telegraphy, through an introduction to Sir Charles Wheatstone, during a visit to London, and he subsequently studied and experimented in telegraphic science. He applied the knowledge he thus gained to the cause in which he was most interested, namely, the relief of those afflicted with deafness, and no doubt it was his studies in this direction which eventually led him to the problem of reproducing the human voice by electrical means.

He spent a good deal of time towards the production of a multiple harmonic telegraph, by means of which he hoped to be able to transmit several telegraphic messages simultaneously along one wire. It was while thus engaged that Graham Bell had two private pupils both of whom were deaf, one the son of Thomas Sanders, of Haverhill, Massachusetts, and the other the daughter of Gardiner Green Hubbard, of Cambridge, who eventually became his wife. The two gentlemen named became interested in the possibilities of Graham Bell's experiments with his multiple telegraph, and gave him financial support. The fortunate accident which, on June 2nd, 1875, led to the invention of the telephone has already been mentioned in Chapter I. The first public demonstration of the telephone took place at Brantford on September 21st, 1875; on February 14th, 1876, the patent application was filed at Washington, and on March 7th following patent number 174465 was issued by the United States Patent Office in respect of the invention.

The telephone launched as a practical device, Graham Bell seemed to lose a certain amount of interest in it. He removed to Washington in 1879 and reverted to his former work in the cause of the deaf.

In 1880 Graham Bell was made an Officer of the Legion of Honour by the French Government and was awarded the "Volta Prix" of 50,000 francs. With this money Dr. Bell founded the "Volta Laboratory," an institution devoted to the prosecution of scientific experiment. The University of Heidelberg con-

ferred upon him the degree of M.D. in recognition of his invention for discovering the position of a foreign substance in the human body. He was also the recipient of the Albert Medal.

In 1920 Dr. Bell revisited Edinburgh, his native city, and on November 30th, 1920, the freedom of the city was conferred upon him by the Edinburgh Corporation, "in recognition of his great achievement in the solution of the problem of telephonic communication and of his brilliant and distinguished career as a scientist." Dr. Bell was the first to receive the freedom of Greater Edinburgh.

Among Dr. Bell's other inventions were the photophone or radiophone in 1880, an apparatus for the transmission of speech by means of a beam of light, which had no practical development, and the graphophone in 1887. Out of the money received for these inventions the "Volta Bureau" was founded, for the purpose of conducting scientific investigation and the general advancement of knowledge in the cause of the deaf.

Dr. Bell also founded the American Association for the Promotion of Teaching Speech to the Deaf. His work and interest in the cause of the deaf were maintained throughout the whole of his life.

Dr. Bell also investigated the laws of flight and conducted numerous experiments in aviation.

Included in the numerous offices which he held were President of the American Association to Promote Teaching of Speech to the Deaf, President of the National Geographic Society and Regent of the Smithsonian Institution.

Dr. Alexander Graham Bell passed from this life during the morning of Wednesday, August 2nd, 1922, at his summer residence near Baddick, Cape Breton Island. His remains were buried on Friday, August 4th, 1922, in a grave blasted out of solid rock overlooking the Bras d'Or Lakes. For the brief space of one minute during the ceremony communication was suspended over the entire telephone system of the United States and Canada, and silence reigned for that period over the vast system of wires forming the telephone network of those countries, as a tribute to him whose work had been the means of bringing it into existence.

4. *The Post Office and the Period of the Great War*

In the previous chapters of this volume the author has endeavoured to trace the history of telephony in the United Kingdom from its commencement up to January 1st, 1912, when the State acquired by purchase the telephone system of the National Telephone Company. With the passing of the National Telephone Company's administration into the hands of the British Post Office, the author's specific task is ended. More than twelve years have passed, however, since that event occurred, and these records would perhaps be considered incomplete without some reference to the more important events and developments associated with the Post Office administration of the telephone service within that period.

On January 1st, 1912, then, the Post Office assumed full control of the whole of the telephone service of the United Kingdom excepting only the systems owned and worked by the Corporations of Hull and Portsmouth and the States of Guernsey.

It was decided that the telephone system should be absorbed by and become an integral part of the huge system of communications which in years gone by had been built up by the Post Office, and steps were therefore taken to weave the telephone administration into the existing fabric of the Post Office organisation.

The employees of the National Telephone Company who were transferred to the Post Office numbered 12,196 established and 6800 unestablished staff, making a total of close upon 19,000; of these some 7000 were engaged almost entirely upon engineering work and therefore were added to the existing staff of the Post Office Engineering Department, numbering at that time approximately 9000, making a total engineering staff of 16,000 controlling and supervising officers and men. The remaining 12,000 were merged with the existing staff of the Post Office engaged upon telephone work other than engineering and continued largely in their previous capacity.

It will perhaps be as well to recapitulate briefly the conditions which obtained at this time relative to the telephone system.

Of the 1565 exchanges purchased from the National Telephone

Company, all of which gave continuous service, 231 accommodated more than 300 lines each; of these 68 were equipped with common battery switchboards, and five with switchboards fitted with self-restoring indicators; the ring through system with lamps accounted for nine, the call wire system for three, and the remainder, including exchanges of less than 300 lines equipped capacity, were for the most part magneto exchanges with hand-restored indicators.

The staff of operators numbered approximately 7550. Nearly 48 per cent. of the subscribers' lines connected to exchanges of 300 lines fitted capacity and over, were equipped for common battery working.

The 561,738 telephone stations acquired from the company included approximately 36,300 private wire stations.

The line plant, comprising 1,500,000 miles of wire, was approximately 65 per cent. underground, 10 per cent. in aërial cable and the remainder open wire.

In London, where the Post Office had been operating actively for ten years, the number of pre-transfer Post Office telephone stations was approximately 77,000. The acquired National Telephone stations numbered 131,500, of which 102,800, equivalent to nearly 80 per cent., were equipped for common battery working.

Table 23 gives the number of National Telephone exchanges of 300 lines and over worked by the several different switching systems, and the number of subscribers associated therewith immediately upon the absorption of the company's system.

In some few provincial towns, and in London, the acquired system consisted largely of overhead wires, due principally to the company's inability to arrange terms for the installation of underground plant, and also to natural reluctance on the part of the company, during the latter years of their tenure of licence, to incur expenditure involving wholesale scrapping of plant.

So far as the ex-Municipal systems were concerned, a good deal of progress had already been made towards the unification of the ex-corporation and national systems in Glasgow, some of which work has been dealt with in Chapter XV, while at Tunbridge Wells, Swansea and Brighton similar steps had been taken.

During the latter years of the company's administration development had not been pressed or specifically provided for by the provision of spare plant, much beyond the time when the company's responsibility ceased and consequently a shortage of spare cable and exchange plant was threatened.

A review of the situation at this period indicated that the task confronting the Post Office in relation to the telephone system included the following :—

(1) To arrange and bring into operation a staff organisation combining the staff acquired from the National Telephone Company with the Post Office telephone staff.

(2) To weld the Post Office telephone trunk line system into the various local systems by combining many of the existing separate local and trunk exchanges.

(3) To instal underground cable systems in substitution for many of the acquired overhead systems and to extend existing underground systems in needful cases.

(4) To modernise those ex-National exchanges containing equipment of obsolescent type by installing new switchboards.

(5) To make provision for future development by the installation of additional underground cables and the erection of new or extension of existing exchange switchboards.

In the Provinces, apart from the severance of the National Telephone Company's engineering staff from the organisation in which it had figured under the company's *régime*, and its transfer to the local engineering staff of the Post Office, the organisation created by the company was continued generally, with some slight modification in order to adjust relationship with the existing Postal organisation.

When, in 1901, the construction work for the telephoning of London by the Post Office was commenced, the single Metropolitan engineering district previously existing was divided into three separate districts, namely Central, North and South, each under the control of an independent superintending engineer. The North Metropolitan district was abolished on May 1st, 1911, the territory being divided between the Central and South Metropolitan engineering districts, some of the more remote portions being transferred to adjacent provincial districts. Thus at the transfer of the National Telephone Company's system to the Post Office, there existed two districts, known respectively as the

Central and South Engineering Districts of London, worked by a staff of approximately 3250. The engineering staff of the company, numbering 1476, was absorbed by these two districts under the control respectively of Sir William (then Mr.) Noble and Mr. Alexander Moir, making a total engineering staff for the Metropolitan area of 4726. On October 1st, 1912, a further adjustment was made by the formation of a single engineering district for London, under the superintendence of Mr. Moir, the district boundary following, as far as practicable, that of the London postal area, certain outlying territory being transferred to neighbouring provincial districts.

On November 1st, 1912, entire reorganisation of the combined National and Post Office engineering staffs was effected in the London engineering district, where a complete scheme of functional organisation, based largely upon that introduced by the National Telephone Company in London in 1905, was brought into operation. The arrangement is still in force, and is illustrated in diagrammatic form in Fig. 184.

The staff of the National Telephone Company, other than engineering, numbering 3186, was combined with the existing Post Office telephone staff of 1710, making a total of 4896, under the Controller of the London Telephone Service, Mr. G. F. Preston, whose association with telephony has been practically lifelong.

During 1912, 1913 and 1914 the Post Office was busily engaged in extending telephone service into rural areas where previously the telephone had never penetrated. In these three years no fewer than 450 exchanges were opened in as many small villages in various parts of the country.

From 1896, when the State acquired the National Telephone Company's trunk line system, up to 1912, when the Company's local systems passed into the hands of the Post Office, no fewer than 287 trunk exchanges were established by the Post Office in various parts of the country. These exchanges were, of course, independent of the local exchanges owned by the National Telephone Company. After the transfer of the Company's system to the State, the old boundaries hitherto recognised by the Company no longer served any useful purpose, and consequently they disappeared. Except in isolated cases there was also no necessity to maintain separate local and trunk exchanges

POST OFFICE LONDON ENGINEERING DISTRICT ORGANISATION

November 1ST, 1912.

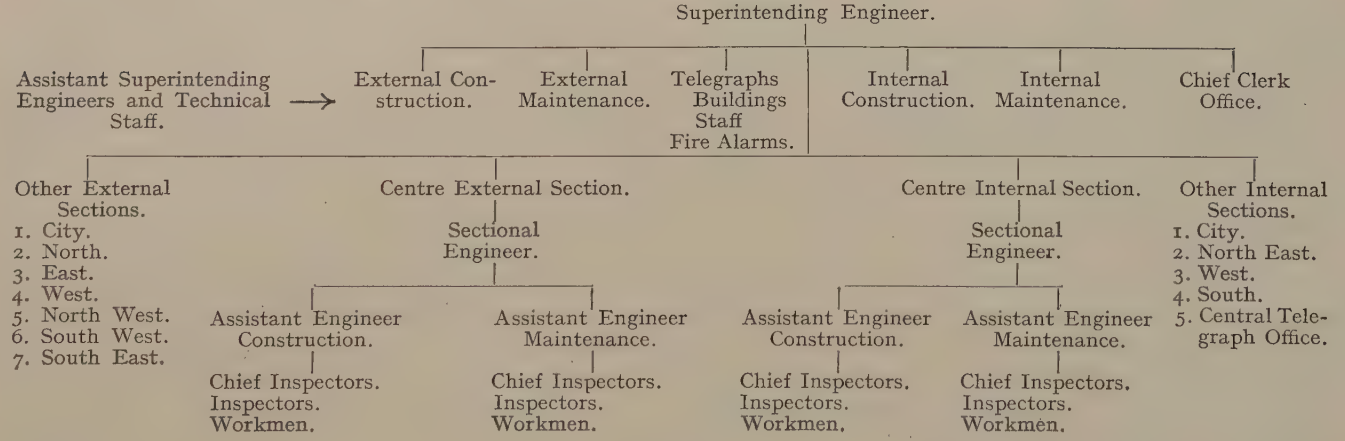


FIG. 184.

in identical areas, and therefore arrangements were made, wherever practicable, for their amalgamation and the conditions which obtained prior to the acquisition of the trunk lines by the State were more or less reverted to.

By the end of 1915 as many as 217 of these trunk exchanges had been closed as a result of the combination of local with trunk exchanges.

Less than three years elapsed from the time the Post Office became wholly responsible for the telephone system and service to the outbreak of the calamitous war with Germany; during that time a good deal had been done towards the unification of the telephone system, but much of the work was of a preparatory nature, and consequently, little comparatively of the old and obsolescent plant, more particularly switchboard plant which existed, had been replaced by modern equipment.

A quantity of overhead had been replaced by underground plant and new underground conduits and cables had been laid to meet the needs of the immediate future. Many comprehensive schemes for the provision of new plant of all classes were in contemplation, or in hand, when progress was, unfortunately but necessarily, arrested by the war, and energies had to be directed to the more urgent needs of the moment, namely to the prosecution of the war to a successful issue.

The services of the highly skilled men of the Post Office Engineering Department were indispensable to the armed forces in the field, in the construction and maintenance of the various forms of electrical and other communication essential in any war, and which, in a war of such huge dimensions, demanded the release of every possible man, even to the detriment of the home telephone service. During the war period some 13,000, a figure corresponding to over 50 per cent. of the total engineering staff of the Post Office, numbering at that time approximately 25,000, upon whom devolved the maintenance of the telephone plant and construction work associated with the telephone service, were liberated entirely for war purposes; those who remained, many of them much against their will, in addition to carrying on the home telephone service under most trying conditions, also undertook services for the armed forces, and associated with the Home Defences, which have never been and never can be adequately realised by the uninitiated. Particulars of the staff released for

war purposes from the Post Office Engineering Department are as follow :—

Controlling and supervising officers	317
Clerks	1,350
Skilled workmen, labourers and youths	10,751
Other grades	423
Royal Engineers, Ireland	106
Total	12,947

Not only was the Engineering Department seriously affected by the release of such a large proportion of its regular staff, but the ranks of the expert female operators, trained and experienced in all the intricacies of manipulating telephone traffic, were also seriously depleted. As a consequence of the opportunities for employment opened up by the departure of every possible able-bodied man of military age for the arena of war, they left their customary occupation in shoals for work of a more lucrative character, or for posts which appeared to present superior prospects of serving their country in the dire extremity in which it was placed.

To repair temporarily the rents thus made in the ranks of those whose normal vocation was identified with the telephone service, recourse was had to the employment temporarily of women, boys and the available men who could be obtained; they possessed no experience whatever of the work they would be called upon to undertake, and measures were taken to give them specially arranged courses of intensive training, in order to fit them as far as possible for their respective duties. Women were employed in the Engineering Department of the Post Office in many spheres where never before had the gentler sex been engaged, such, for example, as the repair and upkeep of overhead telephone lines, the maintenance of subscribers' telephone apparatus and various duties in telephone exchanges. In some cases women were actually employed in excavating trenches for the reception of subterranean telephone conduits which proved to be necessary during the war. Many youths of such tender years as to exempt them from war service were employed temporarily until the attainment of military age, when they were liberated, their short experience in the Post Office frequently proving useful in Army Signal Units.

Of the engineering staff liberated for war service 997 were killed and 2500 wounded.

It is impossible to tell of the war work performed by the staff who normally were engaged in providing for the peace time needs of the telephone user in the United Kingdom. Particulars have already been given of the number of staff taking active part in the military operations. Some idea may, however, be conveyed of the activity displayed by the home telephone staff during the war period. The facility for communication afforded by the telephone system to the Army and Navy and Flying Corps and their many auxiliary services was indispensable to their operations in this country, and in addition to carrying on the usual telephone service much work of a secret nature was done by the Post Office for the naval, military and air forces, the staff being organised to co-operate with them, and in some parts of the country to operate directly under military control in case of emergency.

Elaborate arrangements, involving complex and novel applications of Graham Bell's invention, were made in several parts of the country to aid the Anti-aircraft Defence Forces in their operations. These systems were designed, constructed and to some extent operated by the telephone staff, in co-operation with the military authorities, and played a most important part in protecting the public against raids by German aircraft.

It was no uncommon thing for female operators to be summoned by special means to attend at their respective exchanges in order that they might deal with the telephone traffic originating as a result of the issue of an air raid warning. Numerous indeed were the cases when, with shaded lights, during expectation of attack from unknown directions in the stillness and darkness of the night, traffic was adroitly handled with the nonchalance acquired of long practice and also, what was of even greater consequence, actually amid the noise of anti-aircraft guns, and the more nerve-racking boom of exploding bombs dropped from enemy machines. One case only of devotion to duty in circumstances which would have put the strongest nervous constitution to the severest test will be mentioned.

In an obscure corner of *The Telegraph and Telephone Journal* for October 1916 the following modest paragraph appears :—

" At an exchange on the North-east coast during a recent air raid, the windows were blown in and the property in other ways damaged. The telephonists on duty continued to work the

switchboard and it is understood the Military Authorities have written and complimented them upon their services during the bombardment."

The brevity of this paragraph was dictated by the exigencies of the military situation of the times and it but inadequately describes what befell on that occasion which actually was as follows :—

On the night of Tuesday, August 8th, 1916, zeppelins appeared off the coast of Northumberland and visited Whitley Bay at about 1.0 a.m. on the following morning. Several bombs were dropped in the near vicinity of the telephone exchange, one, within fifty yards of it, completely wrecking an adjacent building and causing other damage. The windows of the telephone exchange, where two operators were busy carrying on their accustomed duty, in response to the requirements of the situation, were blown in, the lights were extinguished, and the whole of the indicators fell as a result of the concussion. The air was filled with dust from the *débris* of the demolished building and bombs continued to be dropped in the neighbourhood. The two operators, Mrs. Mary Alice Binns and Miss Lilian Storey, after regaining their composure, lighted the emergency lights, restored the indicators, and continued to attend at the switchboard. Their courageous action in the interests of the community at Whitley Bay was ultimately recognised, and they duly received the medal of the Most Excellent Order of the British Empire for " displaying great courage and devotion to duty during air raids."

This is but one example of the manner in which the telephone staff acquitted themselves in extremity on similar occasions. Owing to the necessity for suppressing the publication of information likely to be of use to the enemy, such cases of devotion to duty passed almost unnoticed at the time, and it is fitting they should be placed on record here.

The bombardment by a portion of the German Fleet to which parts of the East Coast were subjected at 8.30 in the morning of December 16th, 1914, will be well remembered. Besides the unfortunate loss of life and damage to property occasioned at Scarborough, Whitby and the Hartlepools, considerable damage was done to telephone plant at those places. No vital injury was received by the telephone system, but some 500 subscribers' and other circuits were put out of order and other minor

damage was inflicted, repairs being executed in the course of two days.

Needless to say, the circumstances to which allusion has previously been made deleteriously affected the telephone service

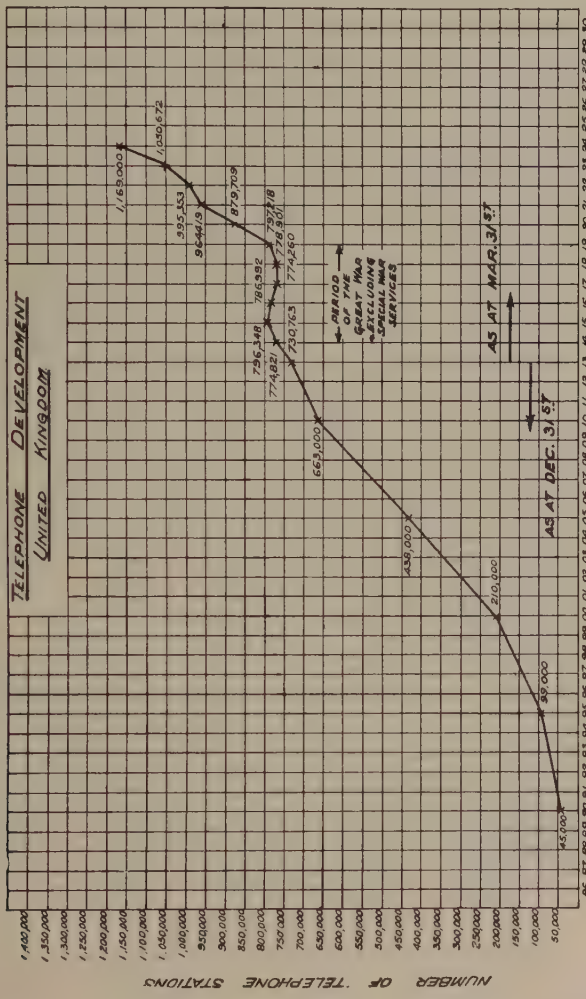


FIG. 185.—Telephone Development in the United Kingdom showing effect of the Great War.

throughout the whole of the country. Despite the utmost endeavours of those who remained in charge, the cumulative effect, over the four years of war, of the absence of skilled maintenance and the consequent unavoidable neglect in upkeep of the plant, coupled with the depreciated condition of much of it at the

outbreak of war, brought the telephone system much nearer the breakdown point than the telephone using public ever imagined. Furthermore, the switchboard plant which existed at the commencement of hostilities was designed to take the pre-war normal load. During the war the telephone was one of the extremely few services not curtailed or rationed as were most commodities essential even to existence. The telephone using public took full advantage of this fact, and, together with the military use which was made of the telephone, the load was increased far beyond that the switchboards were designed to carry and the operators who could be accommodated thereat were able to handle efficiently.

During the period affected by the war, telephone construction was brought almost to a standstill, none but works of imperative necessity being proceeded with. Telephone connections which were essential only in the interests of the nation were added to the system, and the result was a retrograde movement in normal telephone development never before experienced. A graphical representation of the growth of telephone stations in the United Kingdom from December 31st, 1890, to March 31st, 1924, is given in Fig. 185. The effect of the war upon telephone development is indicated by the unprecedented depression in the curve for the war period; telephones provided exclusively for military and allied purposes are excluded. It will no doubt be observed that the loss sustained in the four years of war was almost, but not quite, regained after a further four years, in spite of the difficulties which were experienced. Fig. 186 is a similar graph showing the growth of telephone stations in the Metropolitan area from 1880 to 1924.

For some time after the armistice was declared on November 11th, 1918, the telephone service was carried on under difficulties no less than those which had to be contended with during the war; in fact, those difficulties have not yet disappeared. High, uncertain and fluctuating prices, depletion of highly skilled staff, and general shortage of the widely varying classes of materials and plant employed in telephony have, in a system largely out of date, seriously delayed progress of the schemes for replacement and extension of plant in contemplation at the outbreak of war. In a large number of cases service had to be carried on, and is still being carried on, with plant that is obsolescent and even past its physical life. Furthermore, the numerous demands received for telephone service immediately upon the cessation of hostilities

had to be met as far as possible, and in numerous directions unusual measures had to be taken to meet the exigencies of the moment—measures which in many cases in normal conditions would have been regarded as most undesirable.

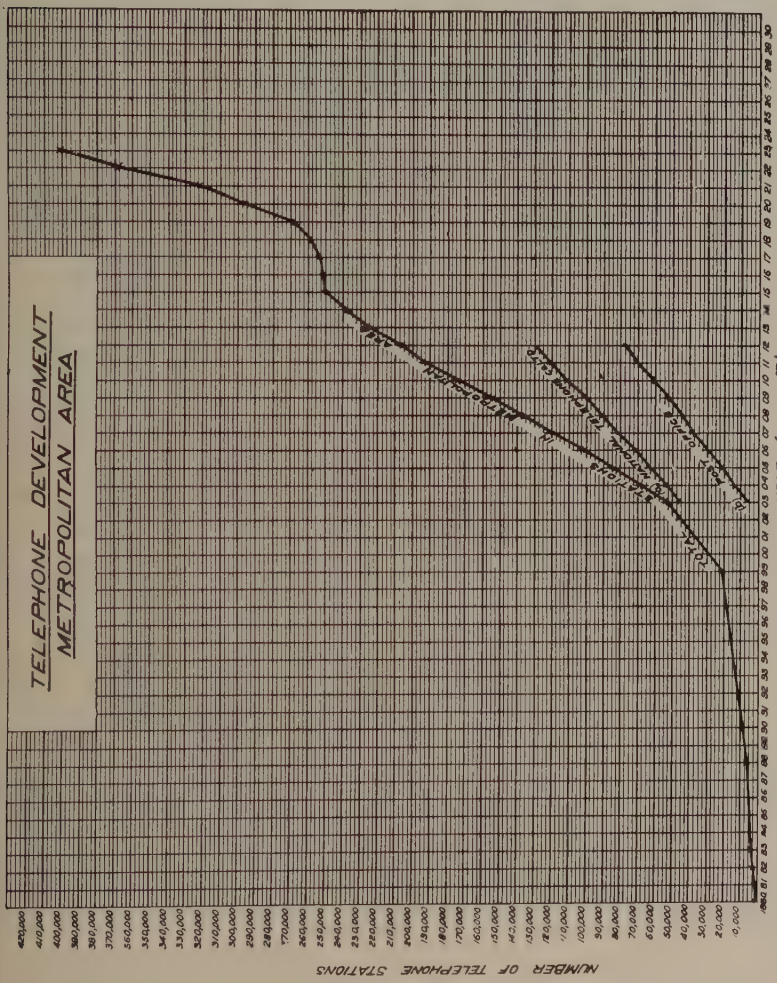


FIG. 186.—Total Telephone Development in Telephone stations in the Metropolitan area, 1880 to 1924.

Bearing in mind the circumstances briefly related in the foregoing portion of this chapter, the reader may perhaps be enabled to appreciate, and to view in proper perspective, the general state of the telephone system, and the conditions in which service was administered in this country immediately after the war. Tersely

stated, the four years of unavoidable neglect in maintenance, and omission to make adequate provision for future growth during the war period, was superposed upon a period of seven years of the National Telephone Company's *régime*, in which obsolescent plant had been permitted to remain in service and to become practically exhausted of "spares," broken only by a respite of less than three years, when little more than the necessary reorganisation and settlement of staff, and preparation of an ambitious programme of work, had been possible. Consequently, the telephone service suffered severely and fell short of the high-water mark of efficiency expected by the telephone user. The more frequent use of the telephone, to which the public had become accustomed during the war, had inculcated more of the telephone habit than ever had existed in this country before, and applications for telephone service, quite impossible to satisfy, began to be received immediately the war was over.

In the House of Commons on July 19th, 1920, the Postmaster-General announced that applications were being received in London at the rate of about 2600 a month and 5300 in the Provinces. During the past twelve months orders had been executed at the rate of 2300 a month in London and 3900 in the Provinces. Nevertheless, on April 30th, 1920, there were 35,000 applications recorded which it had been necessary to refuse on account of lack of plant.

In 1919, when the question of telephone tariffs came under consideration, considerable complaint was made by the telephone public, and in February 1921 the Postmaster-General issued a White Paper explaining in detail the proposed telephone rates.

On March 10th, 1921, it was ordered: "That a Select Committee be appointed to inquire into the organisation and administration of the Telephone Service and the method of making charges."

The first sitting of this Committee was on April 6th, 1921; the proceedings extended over twenty-six days and terminated on July 27th, 1921. In all, 27 witnesses were examined, including representatives of the Post Office, the Press, the Port of London Authority, Glasgow and Hull Corporations, the Association of British Chambers of Commerce, the National Chamber of Trade, Co-operative Societies, the London Telephone Advisory Committee, the Scottish Chamber of Agriculture, the Highlands Reconstruc-

tion Association, the National Farmers' Union, the Bristol Chamber of Commerce and Shipping, the Bristol Corporation Docks and other Associations.

The printed evidence comprised a Blue Book of 314 pages and was ordered for printing on July 27th, 1921.

The report of the Committee was brief and read as follows :—

" Your Committee are of opinion that at this late period of the session it is not in their power to conclude their inquiry. They have therefore agreed to report the evidence already taken to the House and to recommend that a Committee upon the same subject be appointed early in the next session of Parliament."

The total cost of the inquiry was £1540 7*s.* 10*d.*

On February 17th, 1922, it was again ordered : " That a Select Committee be appointed to inquire into the organisation and administration of the Telephone Service and the method of making charges," and on February 20th, 1922 : " That the Minutes of Evidence taken before the Select Committee on the Telephone Service in the First Session of 1921 be referred to the Select Committee on the Telephone Service."

The proceedings of this Committee were recounted and their report published in a Blue Book ordered to be printed on March 20th, 1922, and a Memorandum of visits paid by Sir Evelyn Cecil and Mr. William Wilson Cook (Assessor to the 1921 Select Committee) to Sweden, Norway and Denmark, and of Mr. Cook to the United States and Canada, was also included.

The principal recommendations of the Committee were briefly as follows :—

(1) Separation of the telegraph and telephone departments from that of mails; reorganisation on more commercial lines; constitution of an administrative board of heads of departments under the Postmaster-General or Minister of Communications.

(2) Division of the country into telephone areas for healthy competition and financial comparison.

(3) Greater encouragement of co-operative enterprise where the Post Office do not see their way to develop, notably in rural areas, under Government supervision, by sanction of the Railway and Canal Commission.

(4) Telephone charges to be reduced with the reduction in cost of living and cost of materials.

(5) Financial treatment of depreciation to be revised.

(6) Salaries and overhead charges for new construction work and renewals to be debited respectively to capital and to the depreciation account, not to revenue.

(7) Telephone accounts to be kept in a more commercial form.

(8) The basis of the method of charging to be the message rate. The flat rate for business lines was condemned, but although theoretically objectionable it was admitted to be a means of accelerating development in very small places or for residences in certain restricted areas.

(9) The extra mileage rate to be reduced from £10 to £5 per mile.

(10) A lower annual installation rental for residences than for business premises.

(11) An immediate reduction of 10 per cent. on subscribers' accounts in the event of the Committee's conclusions being approved.

It was pointed out in the report that the Norwegian telephone system, frequently held up for imitation and compared with the British to the disparagement of the latter, was run at a loss ; also that although due weight must be given to the evidence which was tendered to show that the usual business maxim " The greater the output the less the cost " does not apply to telephone development, yet the Committee were inclined to believe that if a comprehensive unit for service to the subscriber is taken for comparison, telephone business will in this respect fall into line with common experience.

Respecting the question of " wrong number " complaints, the Committee stated :—

" . . . From inquiries your Committee have made into specific cases, it is not equitable to assume carelessness or obstruction on the part of the operator. Many of them are models of skill, intelligence and quickness and it is fair and apposite to recall here the telephone aphorism : The fool is always at the other end of the wire."

The Committee's report concluded with the following statement :—

" Your Committee are very much alive to the fact that the financial success of some of these recommendations is dependent

upon a better spirit of co-operation between the Post Office and the public as expressed in § 2. To secure this success, a more sympathetic recognition is vital by the Post Office, on the one hand, that the public are human beings with human feelings and frailties, and not mere automatons for making the telephone accounts balance; and by the public, on the other, that there are often real hidden technical difficulties and that an attitude of chronic suspicion does not help to solve them."

Some particulars of the number of subscribers' lines connected to the different systems of switching working in the United Kingdom at exchanges with 300 subscribers' lines and over, from 1912 to 1924, are given in Table 24.

5. *Radio Telephony*

For the space of forty years telephone communication was dependent upon the employment of a metallic line wire as the medium by which speech frequency electric waves were conveyed, but the past few years have witnessed the introduction of a system of telephony in which the metallic connecting link is dispensed with altogether, transmission being maintained by waves propagated through the ether.

Although this volume has primarily to do with the development of line telephony, neglect to make suitable mention of the now important branch of telephony known as Wireless Telephony, or, as it may more scientifically be termed, Radio Telephony, would be inexcusable, and some brief particulars relative to the development of this latest phase of telephonic science will therefore be included.

The initial establishment of communication by telegraphic means, without the aid of any tangible connecting medium, was a most remarkable scientific feat; probably no previous achievement of man appealed so much to the imaginative mind of the public. The transmission telephonically of the human voice, music and other sounds under similar conditions is, however, even more wonderful.

Wireless telegraphy had been in vogue more than twenty years and had become a much used and reliable form of communication before practical radio telephony was accomplished successfully. Radio telephony was really born of the father science, wireless telegraphy, in a manner somewhat analogous to

that in which line telephony was derived from telegraphy as indicated in the earlier part of this volume. The story of the invention by Senator Marconi in 1895 of the first really reliable wireless detector and the subsequent development of wireless telegraphy is to-day almost common knowledge and as it has been told elsewhere in recent years it will not be dwelt upon here. Suffice it to say that Marconi's invention in 1895 was the culminating point of the endeavours of such workers as Clerk-Maxwell, Oliver Lodge, Hertz, Branley and numerous others.

Since the date of Marconi's invention Wireless has assumed high importance in the interchange of intelligence for the convenience and well being of the community and stands unrivalled for the establishment of rapid communication between places which are isolated or difficult of access.

In July 1897 commercial wireless telegraphy was inaugurated by the formation of Marconi's Wireless Telegraph Company, which to-day remains the premier concern in the development and commercial application of wireless telegraphy.

Experiments and investigation in radio science, in which workers too numerous to mention here participated, continued vigorously after Marconi's invention.

The earliest difficulty encountered in the evolution of a system of radio telephony was the production of a suitable generator of the uniform and continuous high frequency waves essential for radio telephonic transmission.

Duddell's musical or singing arc, followed by Poulsen's modification of it, are phases of wireless development, and to Dr. Poulsen, who first produced a practical generator for continuous high frequency waves, which formed the essential " carrier " whereby speech could be conveyed through the ether, is generally ascribed the invention of wireless telephony. Unfortunately, the Poulsen arc did not possess the requisite stability nor lend itself to the application of a modulating device like the telephone transmitter. It gavè promising results, however, and by its means in 1910 wireless telephonic transmission was successfully accomplished over a distance of several hundred miles.

In 1907 Fessenden, in America, is said to have transmitted speech successfully for a distance of some 200 miles.

Development of the Poulsen arc for radio telephony practically ceased with the advent of the thermionic valve, a really concrete

advance towards the practical application of radio telephony. The first valve was invented and patented by Professor Fleming in 1904. This 2-electrode thermionic valve was based on an effect, generally known as the Edison effect, observed by Edison as long ago as 1883.

Briefly, Edison's discovery, described in a patent specification filed by Edison on November 15th, 1883, was that if a metallic conductor was interposed in the vacuous space within the bulb of an incandescent electric lamp and externally was connected to one side of the filament circuit, a portion of the current traversing the lamp filament was diverted to the metallic conductor through the vacuous space within the lamp.

In 1904, Fleming demonstrated that the contrivance acted as a rectifier for high frequency oscillations, or, in other words, possessed unidirectional conductivity, and was adaptable as a detector for wireless telegraphy. Two years later Dr. Lee de Forest, in America, added to the Fleming valve a third electrode, which he termed the "grid," a combination which he named the "audion." By this means, to the rectifying properties of the Fleming valve was added that of the amplification of high frequency oscillations.

Since the invention of the grid by Lee de Forest, many scientific workers have been engaged in the improvement and development of the 3-electrode valve, and from it ultimately emerged the modern thermionic valve which has placed radio telephony on a practical and commercial basis, and which is such a common feature of broadcasting receiving sets in use at the present time.

A great part of the development of the audion, and of its application to telephony, was carried out in the Western Electric Company's Research Laboratories, under Dr. F. B. Jewett, and by engineers of the American Telephone and Telegraph Company, under Colonel Carty.

Great advances in practical radio telephony occurred during the late war, largely in connection with aviation, when not unnaturally, for reasons which will be obvious, the improvements and developments made were not widely advertised.

In 1915 speech was transmitted by the American Telephone and Telegraph Company from the United States Naval Wireless Station at Arlington to the Eiffel Tower in Paris.

At the time of the introduction of practical radio telephony there were scattered throughout the kingdom a number of enthusiastic experimenters in wireless telegraphy, licensed by the Postmaster-General, to work wireless receiving, and in some cases transmitting, apparatus. As soon as radio telephony became practicable certain transmitting stations began to radiate telephony intermittently.

The first regular transmissions of telephony authorised by the Postmaster-General commenced on Tuesday, February 14th, 1922, under the auspices of the Marconi Scientific Instrument Co., Ltd., from the station at Writtle, near Chelmsford, Code 2 MT. Similarly, Marconi's Wireless Telegraph Company began to transmit at stated intervals items of music, etc., from Marconi House, Strand, under the now well known Code 2 LO. In this way broadcasting was commenced.

Immediately telephony began to be radiated, not only from British, but also from certain Continental stations, notably The Hague and Eiffel Tower, experimenters who previously had devoted themselves to radio telegraphy embraced also the new science, and their numbers were soon swollen by addition to their ranks of many new-comers. The applications for experimental licences increased enormously, and by June 1922 some 11,000 receiving and 450 transmitting licences had been issued by the Post Office.

The circumstances which followed the invention by Graham Bell of his magneto telephone, and of the microphone by Professor Hughes, when amateurs and others who became interested experimented with the new devices, and constructed their own receivers and microphones, were repeated, but on a very much larger scale. Legitimate experimenters, amateurs of all classes both young and old, and even the ubiquitous schoolboy became infatuated with the wireless idea, and receiving sets of all sorts and descriptions were constructed, or merely assembled from purchased parts. The subject became, and remained for some time, the one absorbing topic of conversation. A new industry was created; manufacturers organised to meet the demand and salesmen enlarged their establishments or opened new shops to satisfy the wants of the public in things " wireless."

An important milestone in the progress of radio telephony was reached during the evening of Sunday, January 14th, 1923, when

arrangements made by the Western Electric Company, in conjunction with the Radio Corporation of America, resulted in the establishment, experimentally, for some two hours of communication by radio telephony across the Atlantic Ocean. The arrangements at this end were in the hands of Mr. Frank Gill, European chief engineer to the International Western Electric Company.

The experiments were conducted with a view to ascertain the technical possibilities of communicating by telephony between the two continents of Europe and America. Communication was one way only, the transmitting aerial being that of the Radio Corporation, situated at Rocky Point, Long Island, and the receiving station at the Western Electric Company's factory at New Southgate, London. Receipt of the messages sent was acknowledged and confirmed by cable. A period when practically the whole of the Atlantic Ocean was in darkness was chosen. Accounts of this modern achievement of radio telephony were given in the Press at the time, and on February 22nd, 1923, a paper, entitled "Trans-Oceanic Wireless Telephony," was presented at a meeting of the Institution of Electrical Engineers, by H. W. Nichols, Ph.D., of the engineering department, Western Electric Company, who was engaged upon investigations concerning signal strength, atmospheric interference, etc., in this country, preparatory to the attempt to establish actual communication, with which also he was intimately associated.

The practical and more serious uses of radio telephony are at present somewhat limited, and it seems likely to continue for some time to be the handmaiden of line telephony, which it is unlikely to supplant in any material degree. As a means of disseminating intelligence, music, speeches, and the like, it is, however, unrivalled, and its development in this direction in such a short time, under the term of broadcasting, has been phenomenal.

In November 1922 the British Broadcasting Company was promoted under licence granted by the Postmaster-General, by virtue of his monopoly in electrical communications bestowed by the Telegraph Acts. Some six of the leading electrical firms were the prime movers and guaranteed the requisite capital, and over 800 manufacturers became members. Broadcasting programmes were officially inaugurated on November 14th, 1922. 2LO, the code of the London station, first situated at Marconi House,

became known universally, and ultimately transmission from 2LO was received, not only in every corner of the United Kingdom, but on the Continent, and even in various more remote parts of the world.

Following is a list of the British Broadcasting Company's stations now in operation, with the dates of the official openings, codes and present wave-lengths :—

Station.	Code.	Date of official opening.	Wave-length in metres.
London.	2 LO	November 14th, 1922.	365
Manchester.	2 ZY	November 15th, 1922.	375
Birmingham.	5 IT	November 16th, 1922.	475
Newcastle-on-Tyne.	5 NO	December 24th, 1922.	400
Cardiff.	5 WA	February 23rd, 1923.	351
Glasgow.	5 SC	March 6th, 1923.	420
Aberdeen.	2 BD	October 10th, 1923.	495
Bournemouth.	6 BM	October 17th, 1923.	385
*Sheffield.	6 FL	November 16th, 1923.	301
*Plymouth.	5 PY	March 28th, 1924.	335
*Edinburgh.	2 EH	May 1st, 1924.	328
*Nottingham.	5 NG	September 16th, 1924.	322
*Liverpool.	6 LV	June 11th, 1924.	315
*Leeds.	2 LS	July 8th, 1924.	346
*Bradford.			310
*Hull.	6 KH	August 15th, 1924.	335
Belfast.	2 BE	October 24th, 1924.	435
*Stoke-on-Trent.	6 ST	October 21st, 1924.	306
*Dundee.	2 DE	November 12th, 1924.	331

* Relay Stations.

Experiments in transatlantic telephony were continued by the American Telephone and Telegraph Co. and the Radio Corporation of America in conjunction with the Western Electric Co. in this country. In April 1923, the Postmaster-General appointed a Committee, under the chairmanship of Sir H. B. Jackson, G.C.B., Admiral of the Fleet, for the purpose of investigating the possibilities of communication by radio telephony across the Atlantic as a practical commercial project; the Post Office Engineering Department, on behalf of the Committee, participated in further experiments for the purpose of obtaining information as to the possibilities of instituting a reliable system of communication, and weekly transmissions were conducted for some time. Under favourable conditions speech received from America was on some occasions distributed to certain

telephone subscribers in this country by means of their ordinary telephone lines.

The success achieved has been such that the equipment of an experimental transmitting station of 200 kilowatts at the new Post Office station at Rugby, now in course of construction, is contemplated. This will enable two-way conversations to be conducted, and it is anticipated that the possibilities of establishing communication, under favourable atmospheric conditions, between telephone subscribers in this country and in America will be demonstrated.

On May 13th, 1923, speech was transmitted from London by land line to Birmingham, Manchester, Glasgow, Cardiff and Newcastle-on-Tyne, and simultaneously broadcasted from these places. Thereafter, by arrangement with the Post Office, trunk lines between London and the company's broadcasting stations were requisitioned regularly, in order to admit of interchange of programmes. This arrangement enabled the possessors of simple crystal receiving sets with limited range to participate in distant programmes. The regular and highly satisfactory transmission accomplished bears testimony to the excellence of the Post Office overhead trunk line system.

The Western Electric Company's achievement of January 14th, 1923, in successfully bridging the Atlantic by wireless telephony, was followed by the transmission between the two continents of portions of broadcasted programmes, some of those received in this country being relayed by the British Broadcasting Company, and retransmitted from their several stations on the normal wave-lengths. Possessors of the simplest form of crystal receiving set were thus enabled to listen to music, songs and speech transmitted from America.

During the winter of 1923–1924, amateurs in America and in Europe were successful in receiving broadcasted programmes from across the Atlantic, and some few established two-way communication, one with another, between the two continents.

At midnight on December 31st, 1923, to herald in the new year, the distinctive tones of Big Ben were broadcasted throughout the country for the first time, this feature afterwards becoming one of daily occurrence.

During the evening of Monday, May 19th, 1924, the song of a nightingale, in its natural haunts at Oxted, Surrey, was success-

fully transmitted by land line to London and broadcasted simultaneously from all stations.

An experimental broadcasting station of the relatively high power of from fifteen to twenty kilowatts was brought into use at Chelmsford (Code 5XX) on July 9th, 1924, for the purpose of ascertaining the practicability of, and advantages to be derived from broadcasting on a wave length of 1600 metres. The experiment was successful, and it is anticipated that a permanent station of similar character will be established in the near future, in some suitable situation approximately in the centre of England.

The original licences issued for broadcasting provided only for the use of wireless receiving sets approved by the Postmaster-General, and bearing the official seal of the Broadcasting Company, an annual fee of 10*s.* being charged. No provision was made for the use of home-made sets, but by the early summer of 1923 the large proportion of listeners were those who had themselves constructed their own sets, and as a consequence held no licence at all. This contingency was never anticipated when the initial arrangements were in contemplation. The Broadcasting Company derived no revenue from these "pirates," as they were commonly called, and, following an agitation, the Postmaster-General appointed a Parliamentary Committee to consider and report upon broadcasting in all its aspects. The report of this Committee was published on September 23rd, 1923, and eventually it was arranged that "interim licences" should be made available to owners of unlicensed receiving sets, and "constructors' licences" for those who desired to construct or assemble their own sets, both at an annual charge of 15*s.*, while the old B.B.C. licence, authorising listeners to employ a receiving set bearing the official stamp of the British Broadcasting Company, remained. The new licences were available in October 1923, and during that month 298,000 licences were granted, making the total up to that time 492,000; thus British broadcasting became satisfactorily established upon a substantial basis, and by March 31st, 1924, the total number of receiving licences issued was approximately 720,000; at the end of August 1924 this figure had increased to 912,000.

By the wise measures of control adopted here, this country was saved from the chaos which resulted in America from the omission to make arrangements of a similar character.

In the development of broadcasting, many special problems in telephony, not previously encountered in exactly the same form, were presented. One only of these, which will briefly be referred to, was the production of a transmitting device specially suited to the requirements of the new art.

In some respects the problem was similar, in others dissimilar, to that met with many years ago in electrophone working, referred to in Chapter X, when a granular carbon transmitter of special design was adopted. Owing to the new conditions created by the rapid development of broadcasting, attention was again directed to the subject, and the production of several interesting transmitting devices was the result.

Numerous transmitters of various known designs were first experimented with, and even the old Blake transmitter was placed under trial because of its now ancient reputation for faithful articulation.

The ability to amplify speech currents afforded by the thermionic valve renders possible the employment of a transmitter of the diminished sensitivity which, unfortunately, results from reduction of resonance effected for the purpose of annulling distortion; otherwise the infinitesimally small variation in current value, resulting from the reduced sensitivity, would be prohibitive.

One outcome of the attention recently devoted to transmitter design was an instrument of high efficiency of the condenser type. It consists of two discs arranged in the same plane, one rigid, the other of steel which serves as a diaphragm, and is free to vibrate in front of the other, from which it is separated by a layer of air no more than one-thousandth of an inch in thickness. This instrument is said to have given good results at distances of as much as thirty and forty feet. It is worked in conjunction with a two stage amplifier.

The high quality microphonic transmitter of the granular carbon type, employed in the Western Electric Public Address System, has also been used for broadcasting. It has a diaphragm of duralumin, and possesses great volume, therefore requiring less amplification, but its performance is not considered so good as that of the condenser transmitter.

A still later production is the magnetophone transmitter, developed by Captain H. J. Round, of Marconi's Wireless Telegraph Co., Ltd., first brought into practical use at the London

station of the British Broadcasting Company. This instrument operates upon exactly the same principle as the original magneto telephone of Graham Bell when used as a transmitter. The Round magnetophone—or Sykes microphone, as also it has been termed, because of the embodiment in it of principles contained in certain patents of Mr. Adrian Sykes—comprises, essentially, an electro-magnet in the form of a hollow cylinder of steel, open at one end, closed at the other, with a central steel core, the coils of wire which serve for magnetisation being wound in the space between the core and the cylindrical case. In the space between the centre and annular poles of the electro-magnet—*i.e.*, at the open end of the cylinder—in which exists an exceptionally strong magnetic field, by virtue of some 40 watts of electrical energy circulating round the magnetising coils, is loosely supported a very light flat coil of fine silk covered aluminium wire, wound in the form of a disc, to which sufficient rigidity is imparted by securing it to a paper ring of dimensions similar to the coil. Sound vibrations, impinging upon the flat coil, which serves the purpose of a diaphragm, and therefore forms the moving part of the instrument, cause it to vibrate in the magnetic field, and minute electromotive forces, varying in intensity in unison with the sound vibrations, are propagated in the wire coil.

By means of a specially designed amplifier of five stages, these minute currents are magnified, before being passed to the control apparatus for further amplification.

The author is indebted to Captain P. P. Eckersley, chief engineer of the British Broadcasting Company, for certain of the foregoing information.

Perhaps one of the finest achievements of the British Broadcasting Company, both of organisation and of technique, when their previous efforts were eclipsed by what was afterwards referred to as a triumph of skill and organisation, was one which took place at a time when this manuscript was receiving its finishing touches, preparatory to being placed in the hands of the publishers, and happily, therefore, opportunity was afforded for mention of it to be included. The occasion was the opening of the British Empire Exhibition at Wembley, on Wednesday, April 23rd, 1924, when, in the morning, the entire programme accompanying the opening ceremony was transmitted by the aid of the ordinary telephone trunk lines, and broadcasted from

the several broadcasting stations. Speeches by H.M. the King, H.R.H. the Prince of Wales, and a prayer by the Bishop of London were successfully transmitted, and clearly and distinctly heard by innumerable listeners scattered over the United Kingdom, as also the music of massed bands, the singing of a massed choir of some ten thousand voices, and the various noises peculiar to the assemblage of a vast concourse of people.

It transpired afterwards that the King's speech was heard by an amateur wireless enthusiast in New York.

Not only was the King's speech broadcasted in the manner indicated to hosts of his subjects scattered throughout the United Kingdom, but special arrangements were made within the Stadium at Wembley, where the opening ceremony took place, for the convenience of the 150,000 people there assembled. In ordinary circumstances, but few comparatively of this huge number would have been able to hear, still less to comprehend, the King's words, but by the aid of the Western Electric Company's Public Address System of telephony, specially fitted for the occasion, the speech was rendered intelligible to one and all of the assembly.

Seven loud speaking projectors, arranged radially, so as to command the whole of the Stadium, were contained within the canopy of the Royal Pavilion. These projectors, which were ten feet six inches long, were coupled up to the usual transmitting apparatus, and it is doubtful whether the majority of the people present were conscious of the effect of these powerful loud-speakers, although they were enabled by their means to hear each word the King spoke.

This public address system consists of an arrangement of loud speaking telephones coupled by metallic lines to one or more transmitters, associated with valve amplifiers, and it must not be confounded with broadcasting, as, unfortunately, already has been done by a non-technical Press. The Western Electric Public Address System, as such, utilises metallic lines, and is therefore distinct from broadcasting by radio telephony.

Another feat accomplished on the same day, not hitherto attempted publicly, was the reception of the King's speech at the Hayes works of the Gramophone Company upon a loud speaking telephone, from which it was transferred to a gramophone record. By means of this record, during the evening of

the same day, the speech was again broadcasted from the Broadcasting Company's London studio, so that those who were not privileged to hear the speech when delivered in the morning, were enabled to enjoy a reproduction of it some few hours later.

Particular historic interest attaches to this occasion when, through the instrumentality of radio telephony, for the first time in history, millions of his subjects scattered throughout the United Kingdom were enabled simultaneously to hear the voice and listen to the words of King George V.

6. *Conclusion*

This brief account of the progress of the telephone system since the absorption of the National Telephone Company's undertaking in 1912 and of the introduction of practical radio telephony brings the author to the end of his self-appointed task. Probably at some future date an abler pen will resume the story more comprehensively from the point at which it ceases here. The author is conscious that his work is incomplete and that there are many gaps in the story. It necessarily must be so, for, as will probably be inferred by the reader after perusal of some of the foregoing chapters, there are but few records available of the work of those who were responsible for the introduction and early development of the telephone in this country, and of the early telephone companies.

The information contained in some of the chapters will, it is believed, be sufficient to denote that the vicissitudes and tribulations through which the telephone has passed since its introduction into this country have rendered its life a most eventful one, and have exercised an injurious influence upon its commercial and technical development. The telephone service is one of national importance, in which competition is wasteful, and dual control cannot be other than detrimental.

A telephone system never can be comparable with water, gas, tramway and electric light and power undertakings, as some seem to imagine. The latter mentioned services, although for the public benefit, are purely of local interest and utility; they are self-contained and have no relationship whatever with similar undertakings in other localities. The telephone system, on the other hand, spreads its tentacles into almost every corner of the United Kingdom and even beyond. The immensity of the

system, and the complexities arising out of the possible combination of circuits which may be involved in establishing a connection on demand, may be appreciated when it is remembered that, at the present time, there are over one million telephone stations scattered throughout the country, and that, with some few exceptions, a subscriber situated at one such station may demand, and may expect connection with, any other with tolerable accuracy and rapidity. Thus each subscriber's line and every long-distance circuit are intimately related one to another. Break that relationship by the establishment of competition or of dual control and the quality of the service is at once jeopardised and its cost prejudiced.

The circumstances associated with the development of the telephone in this country have been such that much as standardisation of plant, apparatus and material and methods of working is desirable, comparatively little has yet been possible of achievement in this direction. It is true that in many respects the practice of the Post Office was similar to that of the National Telephone Company, and that the plant of the corporations which instituted telephone service some years ago was subject to approval by the Post Office; nevertheless, many disparities were unavoidable, and these were all additional to those which arose necessarily from the early obsolescence of plant caused by the rapid technical advances. Under one administration that very desirable feature, standardisation of plant, method and practice can be much more readily attained. As a perusal of this volume should show, history has repeated itself in demonstrating that competition in the administration of telephone service is wasteful and that dual control tends towards inefficiency.

A telephone system is one of the most useful products of engineering science, but it is a highly complex organisation comprising some of the most delicate apparatus and plant of widely divergent types; its design, construction and manipulation involve technical skill and organising ability of the highest order, and success can only be attained by continuous application of that skill and ability when it is free from the disruption which ensues from unnecessary alterations in administration and unwise changes in ownership.

Apart from that portion of Ireland which has recently been separated in its telephone administration from the remainder of

the United Kingdom, the telephone system of this country is now under unified control with the single exception of Hull, the sole survivor of Municipal telephone enterprise. Unity of control secured at last, let it be hoped that nothing will again lead to disunited administration of the telephone services.

TABLES

TABLE 1.

COMPARATIVE STATEMENT SHOWING FINANCIAL POSITION OF THE UNITED TELEPHONE COMPANY, LTD.

Extracted from the Report of the Directors for year ending April 30th, 1889.

Year.	Metropolitan District, Annual Revenue.	Rentals accrued and Sundry Receipts.	Expenses.	Net Revenue.	Dividend.		Reserve Accounts.	Carried forward.
					Amount.	Rate per Annum.		
	£	£	£	£	£		£	£
1881	23,017	20,645	20,274	371	Bonus	of 10s.	4,045	371
					per	share		
1882	37,520	42,625	21,050	21,574	19,583	5%	6,345	2,362
1883	60,105	61,826	38,374	26,452	24,000	6%	12,364	4,814
1884	72,944	92,345	47,088	44,656	34,409	8%	60,275	5,061
1885	84,385	103,000	46,408	56,592	43,804	10%	76,863	5,291
1886	95,655	122,284	54,681	67,602	57,992	13%	97,233	2,285
1887	100,899	130,704	66,955	63,750	58,182	13%	102,646	4,054
1888	107,750	143,135	73,519	69,615	67,133	15%	116,521	1,564
1889	117,441	152,805	58,541	94,264	87,500	17½%	126,201	—

TABLE 2.

THE UNITED AND SIX SUBSIDIARY TELEPHONE COMPANIES' JUNE 1887 STATISTICS.

	Paid up Capital. £	Gross Receipts. £	Net Receipts. £	No. of Exchanges.	No. of Exchange Subscribers.	No. of Private Wires.	Calls per day.	Total Mileage of Wire.
United Telephone Co.	447,555	100,542	62,235	25	4,622	1,003	74,462	7,500
National Telephone Co.	735,000	92,000	34,178	91	6,729	1,125	70,000	9,000
Lancashire and Cheshire.	380,000	87,050	28,050	48	3,788	1,347	55,000	6,360
Northern District.	196,970	6,100	3,776	12	441	122	4,250	941
Telephone Co. of Ireland.	212,346	9,997	3,629	6	856	94	3,790	668
Western Counties.	354,452	17,750	3,184	14	1,273	400	9,810	1,489
South of England.	332,866	11,500	1,786	23	1,203	370	6,000	1,000
Totals	2,659,189	321,939	136,828	219	18,912	4,461	223,342	26,958

TABLE 3.

TERRITORIAL DIVISION OF THE UNITED KINGDOM ADOPTED BY THE NATIONAL TELEPHONE COMPANY, LTD., 1893–1912.

Area.	Headquarters.	Superintendent.	Year.
Metropolitan	London	Augustus Calder, Manager	1892–1893
		Superintendent	1893–1896
		C. B. Clay, Superintendent	1896–1912
Southern	London	C. B. Clay	1893–1896
		G. F. Preston	1896–1901
		C. J. Phillips	1901–1912
Western	Bristol	C. B. Clay	1893–1896
		R. Shepherd	1896–1905
		R. A. Dalzell	1905–1912
Midland	Birmingham	A. Coleman	1893–1912
North-Western	Liverpool	R. H. Claxton	1893–1905
		R. Shepherd	1905–1912
Northern	Leeds	J. C. Chambers	1893–1912
Scotland	Glasgow	F. Douglas Watson	1893–1912
Ireland	Dublin	F. Gill	1896–1902
		F. Cowley	1902–1912

TABLE 4.

THE NATIONAL TELEPHONE COMPANY, LTD. FINANCIAL RESULT FOR EACH YEAR, 1890–1910.

Year ending 30th April.	Income accrued in respect of the Business of the Year.	Less Post Office Royalties.	Net Income.	Working Expenses.	Net Result for the Year.	Percentage of Working Expenses to Net Income.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	
1890	380,075 3 3	30,493 13 11	349,581 9 4	157,590 1 3	191,991 8 1	45·08
1891	431,112 11 11	36,581 12 4	394,530 19 7	199,483 15 8	195,047 3 11	50·56
1892	463,741 5 4	40,239 5 8	423,501 19 8	236,252 0 5	187,249 19 3	55·78
1893	583,590 2 11	54,220 9 10	529,369 13 1	311,644 10 2	217,725 2 11	58·87
Ending Dec. 31st.						
1894	738,680 16 6	67,222 13 8	671,458 2 10	392,281 17 2	279,176 5 8	58·42
1895	819,034 14 1	74,674 13 1	744,360 1 0	424,164 12 8	320,195 8 4	56·98
1896	870,745 18 0	79,266 18 3	791,478 19 9	469,972 13 1	321,506 6 8	59·37
1897	984,556 14 11	89,238 16 1	895,317 18 10	544,882 2 2	350,435 16 8	60·86
1898	1,112,666 5 0	104,029 18 7	1,008,636 6 5	615,563 11 2	393,072 15 2	61·02
1899	1,266,163 5 1	123,061 6 7	1,143,101 18 6	686,800 12 5	456,301 6 1	60·08
1900	1,432,696 6 7	140,074 7 11	1,292,621 18 8	808,180 18 6	484,441 0 2	62·52
1901	1,576,209 15 0	146,578 8 8	1,429,631 6 4	898,304 17 11	531,326 8 5	62·83
1902	1,691,705 16 1	154,407 12 6	1,537,298 3 7	951,299 8 11	585,998 14 8	61·88
1903	1,835,843 3 4	168,248 16 9	1,667,594 6 7	1,036,698 5 0	630,896 1 7	62·16
1904	2,018,979 16 7	185,937 6 9	1,833,042 9 10	1,154,695 18 9	678,346 11 1	62·99
1905	2,212,358 18 5	206,455 7 5	2,005,903 11 0	1,275,161 1 11	730,742 9 1	63·57
1906	2,436,994 13 1	231,847 18 9	2,205,146 14 4	1,402,230 3 7	802,916 10 9	63·59
1907	2,702,228 1 10	257,919 12 6	2,444,308 9 4	1,530,092 16 11	914,215 12 5	62·60
1908	2,951,000 12 1	283,758 1 11	2,667,242 10 2	1,687,535 3 8	979,707 6 6	63·27
1909	3,149,126 2 8	302,984 5 11	2,846,141 16 9	1,813,490 13 9	1,032,651 3 0	63·72
1910	3,422,423 8 9	329,494 10 4	3,092,928 18 5	1,987,356 17 7	1,105,572 0 10	64·25

TABLE 5.

TYPES OF DRY CORE RUBBER-COVERED CABLE EMPLOYED BY THE NATIONAL TELEPHONE COMPANY.

	20 lb. per mile.	10 lb. per mile.	6½ lb. per mile.
Conductor Resistance in ohms per circuit mile at 60° F.	88 ω	176 ω	272 ω
Electrostatic Capacity	0·0700 × 10^{-6} Farads.	0·0775 × 10^{-6} Farads.	0·0785 × 10^{-6} Farads.
Specified Insulation Resistance in megohms per mile	1,000 Ω	1,000 Ω	1,000 Ω
Diameter of Conductor in mils	35·38	25·01	19·5 to 20·5
Nearest Gauge S.W.G.	20	23	25

No. of pairs.	20 lb. per mile.		10 lb. per mile.		6½ lb. per mile.	
	Weight in lb. per yard.	Approx. diameter, inches.	Weight in lb. per yard.	Approx. diameter, inches.	Weight in lb. per yard.	Approx. diameter, inches.
10	0·75	0·735	0·520	0·610	0·552	0·570
15	1·086	0·885	0·798	0·720	0·723	0·710
25	1·698	1·085	1·221	0·930	0·958	0·880
35	2·094	1·235	1·500	1·030	1·156	0·970
50	2·781	1·432	1·827	1·130	1·491	1·090
75	3·615	1·735	2·250	1·230	1·902	1·190
100	4·587	1·985	3·000	1·480	2·347	1·420
150	—	—	3·420	1·780	2·970	1·690
200	—	—	5·340	2·050	3·987	1·950

TABLE 6.

COMMON BATTERY EXCHANGES OPENED BY THE NATIONAL TELEPHONE COMPANY IN THE METROPOLITAN AREA.

Exchange.	Date opened.	Type.
Kensington	December, 1901	C.B. No. 1
Battersea	February, 1902	Kellog
London Wall	March, 1902	C.B. No. 1
Holborn	May 14th, 1904	,,
North	December 17th, 1904	,,
Sydenham	September 30th, 1905	,,
Brixton	October 13th, 1906	,,
East	May 26th, 1906	,,
Hop	March 17th, 1906	,,
Gerrard	September 28, 1907	,,
Hammersmith	December 7th, 1907	,,
Paddington	March 9th, 1907	,,
East Ham	January 11th, 1908	C.B. No. 9
Enfield	April 15th, 1908	,,
Tottenham	May 18th, 1908	,,
Bromley	August 14th, 1909	C.B. No. 1
Dalston	May 15th, 1909	,,
Walthamstow	September, 11th, 1909	C.B. No. 10
New Cross	October 16th, 1909	C.B. No. 1
Streatham	January 22nd, 1910	,,
Lee Green	February 5th, 1910	,,

TABLE 7.

TYPES OF DRY CORE LEAD-COVERED CABLE EMPLOYED BY THE NATIONAL TELEPHONE COMPANY.

	20 lb. per mile, Low Capacity.	20 lb. per mile, High Capacity.	10 lb. per mile.	6½ lb. per mile.
Conductor Resistance per circuit mile at 60° F.	88 ω	88 ω	176 ω	272 ω
Electrostatic Capacity	0·054 × 10⁻⁶ Farads.	0·0822 × 10⁻⁶ Farads.	0·0714 × 10⁻⁶ Farads.	0·0639 × 10⁻⁶ Farads.
Specified Insulation Resistance in megohms p.m.	1,000 Ω	1,000 Ω	1,000 Ω	1,000 Ω
Diameter of Conductor in mils	35·38	35·38	25·01	20·0
Nearest Gauge S.W.G.	20	20	23	25

No. of pairs.	20 lb. per mile. Low Capacity.		20 lb. per mile. High Capacity.		10 lb. per mile.		6½ lb. per mile.	
	Weight in lb. per yard.	Approx. diameter, inches.	Weight in lb. per yard.	Approx. diameter, inches.	Weight in lb. per yard.	Approx. diameter, inches.	Weight in lb. per yard.	Approx. diameter, inches.
1	—	—	—	—	0·708	0·286	0·465	0·212
2	—	—	—	—	0·876	0·335	0·567	0·242
3	—	—	—	—	1·038	0·380	0·660	0·265
5	—	—	—	—	1·26	0·405	0·792	0·301
8	—	—	—	—	1·371	0·425	—	—
10	—	—	—	—	1·611	0·478	1·045	0·388
15	—	—	—	—	1·899	0·536	1·450	0·439
20	—	—	—	—	2·361	0·590	—	—
25	6·24	1·100	3·66	0·874	2·646	0·640	2·098	0·540
35	6·810	1·250	4·56	0·962	3·012	0·720	2·405	0·605
50	8·019	1·510	5·856	1·140	3·804	0·830	2·950	0·690
75	13·360	1·770	7·539	1·350	4·593	0·932	3·645	0·803
100	15·340	2·040	8·880	1·510	5·67	1·100	4·305	0·900
150	19·66	2·410	14·440	1·855	7·05	1·250	5·448	1·062
200	21·76	2·560	17·118	2·055	8·421	1·400	6·311	1·198
250	—	—	19·920	2·285	12·51	1·650	7·500	1·319
300	—	—	22·240	2·425	14·64	1·830	8·430	1·430
400	—	—	26·120	2·570	16·8	2·000	12·890	1·690
500	—	—	—	—	19·26	2·17	14·800	1·860
600	—	—	—	—	21·78	2·345	16·780	2·013
800	—	—	—	—	25·99	2·55	20·25	2·286

TABLE 8.

DRY CORE CABLE.

20 lb. per mile, Low Capacity.

No. of pairs.	Weight in lb. per yard.	Approximate overall diameter in inches.	Thickness of lead sheath in mils.		Length of lay in inches.
			Min.	Max.	
25	6·24	1·100	85	95	4
35	6·810	1·250	85	95	4
50	8·019	1·510	85	95	4
75	13·360	1·770	85	95	6
100	15·340	2·040	85	95	6
150	19·66	2·410	118	132	6
200	21·76	2·560	118	132	6

TABLE 9.

DRY CORE CABLE.

20 lb. per mile, High Capacity.

No. of pairs.	Weight in lb. per yard.	Approximate overall diameter in inches.	Thickness of lead sheath in mils.		Length of lay in inches.
			Min.	Max.	
25	3·66	0·874	85	95	4
35	4·56	0·962	85	95	4
50	5·856	1·140	85	95	4
75	7·539	1·350	85	95	6
100	8·880	1·510	85	95	6
150	14·440	1·855	118	132	6
200	17·118	2·055	118	132	6
250	19·920	2·285	118	132	6
300	22·240	2·425	118	132	6
400	26·120	2·570	118	132	6

TABLE 10.

DRY CORE CABLE. 10 lb. per mile.

No. of pairs.	Weight in lb. per yard.	Approximate overall diameter in inches.	Thickness of lead sheath in mils.		Length of lay in inches.
			Min.	Max.	
1	0·708	0·286	66	74	4
2	0·876	0·335	66	74	4
3	1·038	0·380	66	74	4
5	1·26	0·405	76	84	4
8	1·371	0·425	76	84	4
10	1·611	0·478	76	84	4
15	1·899	0·536	76	84	4
20	2·361	0·590	85	95	4
25	2·646	0·640	85	95	4
35	3·012	0·720	85	95	4
50	3·804	0·830	85	95	4
75	4·593	0·932	85	95	6
100	5·67	1·100	85	95	6
150	7·05	1·250	85	95	6
200	8·421	1·400	85	95	6
250	12·51	1·650	118	132	6
300	14·64	1·830	118	132	6
400	16·8	2·000	118	132	6
500	19·26	2·17	118	132	6
600	21·78	2·345	118	132	6
800	25·99	2·55	118	132	6

TABLE 11.

DRY CORE CABLE. 6½ lb. per mile.

No. of pairs.	Weight in lb. per yard.	Approximate overall diameter in inches.	Thickness of lead sheath in mils.		Length of lay in inches.
			Min.	Max.	
1	0·465	0·212	66	74	4
2	0·567	0·242	66	74	4
3	0·660	0·265	66	74	4
5	0·792	0·301	66	74	4
8	—	—	76	84	4
10	1·045	0·388	76	84	4
15	1·450	0·439	76	84	4
20	—	—	76	84	4
25	2·098	0·540	85	95	4
35	2·405	0·605	85	95	4
50	2·950	0·690	85	95	4
75	3·645	0·803	85	95	6
100	4·305	0·900	85	95	6
150	5·448	1·062	85	95	6
200	6·311	1·198	85	95	6
250	7·500	1·319	85	95	6
300	8·430	1·430	85	95	6
400	12·890	1·690	118	132	6
500	14·800	1·860	118	132	6
600	16·780	2·013	118	132	6
800	20·25	2·286	118	132	6

TABLE 12.

States of Guernsey Telephone Department.

Statistics Illustrating Growth of Telephone System, 1898–1921.

Extracted from Revenue Statement and Statistics for year ended 31st December, 1923.

Year.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.
Number of Subscribers' Lines.	217	423	606	770	937	1,044	1,162	1,275	1,344	1,405	1,459	1,538	1,584
Public Telephones.	9	20	26	34	37	40	49	49	51	53	59	60	60
Mileage of Overhead and Underground Wire.	298	709·5	1,110	1,443	1885·5,	2,291·5	2,539	2,817·5	3,211·5	3,363·5	4,193	4,319	4,265
Total Number of Calls in the year.	23,172	143,530	257,138	379,342	533,039	679,989	746,398	793,976	879,271	973,884	990,587	1,062,388	1,184,676
Gross Revenue in £.	126	1,047	1,881	2,630	3,483	4,064	4,546	5,004	5,354	5,613	5,864	6,135	6,360
Net Profit in £.	213	135	76	117	157	201	284	233	232	309	380	436	407

Year.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.
Number of Subscribers' Lines.	1,628	1,653	1,725	1,772	1,786	1,824	1,844	1,902	2,041	2,208	2,338	2,532	2,717
Public Telephones.	62	61	63	65	67	67	68	66	68	64	55	56	62
Mileage of Overhead and Underground Wire.	4,358	4,431·5	4,540·7	5,135·5	5,168·5	5,529	5,207	5,610·5	5,801	6,122	6,965	8,909	9,853
Total Number of Calls in the year.	1,283,460	1,299,152	1,366,433	1,571,721	1,590,492	1,436,153	1,536,877	1,634,841	1,654,923	1,668,767	1,625,594	1,721,363	1,958,301
Gross Revenue in £.	6,826	6,840	7,138	7,530	7,511	7,564	7,840	8,251	8,687	10,152	11,931	13,680	14,907
Net Profit in £.	493	607	763	769	540	396	352	212	37	50	811	418	430

[*To face page 662.*

TABLE 13.

PARTICULARS OF POST OFFICE AND NATIONAL TELEPHONE EXCHANGES IN METROPOLITAN AREA, JAN. 1ST, 1912, WITH NUMBER OF SUBSCRIBERS' DIRECT LINES SERVED BY EACH.

National Telephone Company, Ltd.

Exchange.	Subscribers' Direct Lines.	Exchange.	Subscribers' Direct Lines.
Avenue	3,421	Kingston	224
Bank	2,322	Lee Green	1,392
Barnet	91	London Wall	8,804
Bartholomew House	481	Loughton	111
Battersea	1,919	Merstham	56
Bexley Heath	137	Molesey	72
Brixton	1,932	New Cross	1,550
Bromley	1,499	North	3,278
Chigwell	18	Paddington	5,476
Chingford	70	Palmer's Green	614
Cray	76	Purley	42
Croydon	969	Rainham	25
Dalston	2,440	Redhill	355
Dartford	100	Reigate	211
Ealing	241	Richmond	139
East	2,495	Romford	157
East Ham	420	Sidcup	243
Enfield	433	Southall	41
Epsom	64	Stratford	681
Erith	126	Streatham	1,290
Esher	34	Sutton	133
Finchley	131	Sydenham	1,774
Gerrard	8,901	Tilbury	168
Hammersmith	1,057	Tottenham	691
Hampstead	568	Waltham X	132
Harlesden	231	Walthamstow	552
Harrow	20	Wanstead	452
Holborn	4,675	Westminster	1,603
Hop	3,708	Wimbledon	173
Ilford	507	Woodford	240
Kensington	4,468	Woolwich	541

Note.—Bartholomew House Exchange not shown in Fig. 134.

Post Office.

Exchange.	Subscribers' Direct Lines.
Barnet	339
Burgh Heath	134
Central	13,849
Chiswick	1,089
City	4,635
Croydon	907
Ealing	1,004
Epsom	263
Esher	163
Finchley	875
Hampstead	4,745
Harrow	391
Hornsea	1,377
Hounslow	173
Kingsbury	82
Kingston	1,139
Malden	106
Mayfair	6,409
Mitcham	77
Molesey	136
Official	233
Purley	418
Putney	1,416
Richmond	1,068
Southall	63
Sutton	710
Treasury	170
Trunk	109
Victoria	3,908
Wembley	119
Western	5,863
Willesden	956
Wimbledon	1,048

Note.—Official, Treasury and Trunk Exchanges not indicated in Fig. 134.

TABLE 14.

TABLE SHOWING THE DEVELOPMENT OF THE POST OFFICE LONDON TELEPHONE SYSTEM, 1903 TO 1907.

Name of Exchange.	Date of Opening.	No. of Direct Exchange Lines and Telephone Stations as at Jan. 1st each year, 1903–1907.									
		1903.		1904.		1905.		1906.		1907.	
		Direct Exchange Lines.	Telephone Stations.	Direct Exchange Lines.	Telephone Stations.	Direct Exchange Lines.	Telephone Stations.	Direct Exchange Lines.	Telephone Stations.	Direct Exchange Lines.	Telephone Stations.
Central	1/3/02	4,167	4,859	7,587	9,720	9,995	13,315	12,155	16,999	13,741	19,862
Putney	20/5/02	168	183	336	362	474	521	637	695	804	896
Kingston	20/5/02	175	187	288	316	403	446	517	580	668	752
Western	5/8/02	378	394	1,144	1,243	1,710	1,897	2,395	2,664	3,081	3,464
Wimbledon	6/8/02	109	117	215	238	308	348	424	471	564	631
Victoria	12/8/02	369	442	850	1,039	1,251	1,615	1,707	2,310	2,109	2,890
Richmond	7/11/02	94	112	245	283	358	419	524	602	605	693
Chiswick	3/6/03			178	180	360	393	500	553	630	708
Mayfair	20/10/03			725	794	1,520	1,787	2,359	2,924	3,006	3,892
Croydon	26/1/04					181	203	355	390	468	514
Hampstead	27/7/04					883	968	1,797	1,971	2,556	2,808
Epsom	29/5/05							63	66	112	116
Ealing	5/6/05							303	345	471	526
Sutton	9/6/05									225	234
Hounslow	1/7/06									73	87
Harrow	10/10/06									91	100
Wembley	18/10/06									23	29
Malden	11/2/07										
Esher	13/2/07										
Willesden	26/2/07										
Finchley	28/3/07										
Southall	11/9/07										
Hornsey	7/11/07										
Barnet	14/11/07										
City	26/11/07										
Treasury				105	126	113	142	118	155	120	157
Trunk						105	127	103	125	100	124
Total		5,460	6,294	11,673	14,301	17,661	22,181	24,022	30,919	29,447	38,483

TABLE 15.

TABLE SHOWING THE DEVELOPMENT OF THE POST OFFICE LONDON TELEPHONE SYSTEM, 1908 TO 1912.

Name of Exchange.	No. of Direct Exchange Lines and Telephone Stations as at Jan. 1st each year, 1908–1912.									
	1908.		1909.		1910.		1911.		1912.	
	Direct Exchange Lines.	Telephone Stations.	Direct Exchange Lines.	Telephone Stations.	Direct Exchange Lines.	Telephone Stations.	Direct Exchange Lines.	Telephone Stations.	Direct Exchange Lines.	Telephone Stations.
Central	14,696	22,293	13,929	22,474	14,650	24,297	14,542	25,266	13,849	23,870
Putney	926	1,036	1,049	1,195	1,152	1,321	1,302	1,475	1,416	1,592
Kingston	783	899	845	982	964	1,135	1,022	1,212	1,139	1,345
Western	3,697	4,214	4,098	4,928	4,670	5,790	5,398	6,940	5,863	7,342
Wimbledon	665	742	714	802	828	922	935	1,049	1,048	1,184
Victoria	2,451	4,266	2,732	5,637	3,074	5,563	3,440	6,301	3,908	8,178
Richmond	696	813	762	870	862	996	966	1,120	1,068	1,228
Chiswick	709	807	797	908	883	1,003	977	1,135	1,089	1,266
Mayfair	3,548	4,707	3,856	5,347	4,346	6,067	4,862	6,946	5,409	8,078
Croydon	553	594	609	666	687	751	774	852	907	1,019
Hampstead	2,991	3,299	3,416	3,815	3,878	4,326	4,211	4,792	4,745	5,356
Epsom	144	155	172	192	199	221	235	267	263	291
Ealing	577	633	655	730	755	835	845	941	1,004	1,117
Sutton	345	362	420	444	527	560	627	678	710	773
Hounslow	101	120	119	141	144	169	158	186	173	200
Harrow	161	187	220	269	289	345	324	394	391	457
Wembley	41	62	59	82	76	104	93	122	119	146
Malden	25	27	51	55	70	74	99	105	106	113
Esher	62	65	97	103	113	121	130	141	163	176
Willesden	232	250	352	376	530	563	832	877	956	1,043
Finchley	22	22	154	170	440	478	683	742	875	951
Southall	7	9	21	23	35	41	39	53	63	141
Hornsey	287	306	681	743	933	1,026	1,170	1,288	1,377	1,514
Barnet	13	13	96	102	212	234	278	311	339	381
City	129	170	1,474	2,113	1,912	2,969	3,006	4,705	4,635	7,885
Treasury	136	170	140	176	147	183	162	223	170	241
Trunk	98	122	100	124	102	126	109	135	109	137
Total	34,095	46,343	37,618	53,467	42,478	60,220	47,219	68,256	51,894	76,024

TABLE 16.

MECHANICAL AND ELECTRICAL CONSTANTS OF THE TYPES OF IRON, COPPER AND BRONZE WIRES EMPLOYED BY THE BRITISH POST OFFICE.

Material.	Weight per mile in lbs.	Approximate Standard Wire Gauge.	Diameter in mils.	Resistance in ohms per mile.	Minimum Breaking Stress in lbs.
Iron	400	7½	171	13·32	1,240
	200	10½	121	26·64	620
	60	16	66	88·8	—
Copper.	800	4½	224	1·098	2,400
	600	6	194	1·464	1,800
	400	8	158	2·195	1,250
	300	9½	137	2·928	950
	200	11½	112	4·391	650
	150	13	97	5·855	490
	100	14	79	8·782	330
Bronze	150	13	97	12·14	730
	70	16	66	26·0	345
	40	18	50	45·5	197

TABLE 17.

SCHEME OF LOADING CARRIED OUT IN BIRMINGHAM, 1908.

Particulars of lines loaded and results obtained.

Junction.		No. of Junctions.	No. of Loading Points.	Equated Length.	
From.	To.			Before Loading.	Loaded.
Barnt Green	P.O. trunk	5	3	5·6	2 6
Barnt Green	Birmingham Central	5	4	13·1	6·5
Sutton	P.O. trunk	1	2	5·5	1·8
Halesowen	P.O. trunk	3	2	4·4	2·1
Erdington	P.O. trunk	2	2	3·4	1·7
Solihull	P.O. trunk	5	4	—	2·7
Smethwick	P.O. trunk	7	2	3·5	1·2
Acocks Green	P.O. trunk	3	4	6·1	1·8
Oldbury	P.O. trunk	4	4	5·7	1·6
King's Norton	P.O. trunk	5	4	5·2	1·5
West Bromwich	P.O. trunk	9	6	5·9	1·5

The above values are true only when reflection losses at extremities of line are eliminated.

Losses due to reflection will be additional in normal working.

TABLE 18.

EARLY EXAMPLES OF COMMERCIAL LOADING CARRIED OUT BY THE BRITISH POST OFFICE.

Trunk Line.	Date.	Distance, miles.	Type of Conductor.	Type of Coil used.	Coil Inductance in henries.	Spacing of Coils.	Improvement Factor.
Liverpool-Warrington	May 1903	11	100 lb.	Air core	0·045	1 mile	2·75
Manchester-Warrington	Sept. 1904	18·7	100 lb. 40 lb.	Air core	—	1 mile	2·75
Birmingham-Wolverhampton	March 1906	14·25	40 lb.	Air core	—	1 mile	2·75
Cardiff-Newport	April 1906	1·5 11·0	40 lb. 70 lb.	Air core	0·035 0·050 or 0·070	1 mile	4·0*

* No difference observed between the three degrees of loading. Results questionable.

TABLE 19.

PARTICULARS OF STANDARD TYPES OF DRY CORE CABLES ADOPTED BY THE BRITISH POST OFFICE, 1900.

No. of Pairs.	20 lbs. per mile. 35·5 mils diameter. 43·89 ohms per mile.		40 lbs. per mile. 50 mils diameter. 21·94 ohms per mile.	
	External Diameter.	Weight per mile in tons.	External Diameter.	Weight per mile in tons.
7	0·70	2·48	0·880	3·57
12	0·90	3·62	1·15	5·36
19	1·06	4·78	1·35	7·00
27	1·25	5·90	1·60	8·63
37	1·35	6·98	1·75	9·82
48	1·55	8·24	2·05	12·47
61	1·65	9·03	2·20	13·85
75	1·85	10·92	2·45	16·60
91	1·90	11·54	2·60	18·16
108	2·10	13·00	2·85	21·50
217	2·65	19·19	—	—

TABLE 20.

AUTOMATIC TELEPHONE EXCHANGES ESTABLISHED BY THE BRITISH POST OFFICE, 1912–1924.

	Exchange.	Type of Equipment.	Date opened.	Capacity.	
				Of Present Equipment (1924).	Ultimate.
1	Epsom	A.T.M. Co.	March 13th, '15	1,100	1,500
2	Official, London	,,	July 13th, '12	900	1,500
3	Hereford	Lorimer	Aug. 1st, '14	500	900
4	Darlington	W.E. Co., Rotary	Oct. 10th, '14	1,100	2,260
5	Accrington	A.T.M. Co.	March 13th, '15	1,100	1,500
6	Chepstow	,,	July 7th, '15	190	200
7	Newport, Mon.	,,	Aug. 14th, '15	2,000	3,500
8	Portsmouth	,,	April 29th, '16	5,200	7,000
9	Paisley	,,	July 15th, '16	1,700	2,150
10	Dudley	W.E. Co., Rotary	Sept. 9th, '16	500	1,600
11	Blackburn	A.T.M. Co.	Oct. 14th, '16	2,400	4,400
12	Leeds	,,	May 18th, '18	9,600	15,000
13	Grimsby	Siemens	Sept. 14th, '18	1,860	4,000
14	Stockport	,,	Aug. 23rd, '19	1,300	2,260
15	Ramsey	Siemens Village	Oct. 21st, '21	40	80
16	Hurley	,, ,,	Dec. 20th, '21	40	80
17	Fleetwood	Relay Auto. Co.	July 15th, '22	480	700
18	Southampton	Siemens	June 30th, '23	3,200	5,500
19	Hadleigh, Essex	A.T.M. Co., Rural	Feb. 16th, '24	27	50
20	Dundee	North Electric	March 15th, '24	3,500	4,500
21	Broughty Ferry	(Now G.E. Co.)		600	1,000
22	Marton	A.T.M. Co., Rural	March 22nd, '24	80	230
23	Blockley	,, ,,	March 28th, '24	10	25

TABLE 21.

AUTOMATIC TELEPHONE EXCHANGES ON ORDER BY THE BRITISH POST OFFICE, APRIL 1924.

	Exchange.	Type of Equipment.	Capacity.	
			Initial.	Ultimate.
1	Swansea	Siemens	3,200	5,800
2	Sketty	,,	300	500
3	Shrewsbury	A.T.M. Co.	1,000	1,800
4	York	,,	1,700	2,100
5	Torquay	,,	1,400	1,900
6	Paignton	,,	400	500
7	Sheffield Central	Siemens	6,300	9,000
8	,, Owlerton	,,	800	1,200
9	,, Attercliffe	,,	1,000	1,500
10	,, Broomhill	,,	2,400	3,500
11	,, Ecclesfield	,,	200	300
12	,, Beauchief	,,	800	1,300
13	,, Oughtibridge	,,	100	100
14	,, Woodhouse	,,	200	300
15	,, Sharrow	,,	1,500	2,300
16	Leeds Roundhay	A.T.M. Co.	900	1,600
17	,, Headingley	,,	1,300	2,200
18	,, Stanningley	,,	800	1,600
19	,, Chapeltown	,,	900	1,500
20	Gosport	,,	600	800
21	Ipswich	,,	1,560	3,070
22	Brighton (Central)	Siemens	3,360	4,490
23	Bedford	W.E. Co.	—	—
24	Coventry	G.E. Co.	—	—
25	Edinburgh	Siemens	—	—

TABLE 22.

RATES OF SUBSCRIPTION FOR THE LONDON TELEPHONE SERVICE PROVIDED FOR IN THE AGREEMENT ENTERED INTO BETWEEN THE POST OFFICE AND THE NATIONAL TELEPHONE COMPANY, NOVEMBER 18TH, 1901.

Service.	Annual Subscription.	Message Fees.	Extras.
Message Rate. Inside County of London within two miles radius of Exchange.	£5	1*d.* per call to subscriber on any exchange in the County of London, and 2*d.* outside, with minimum payment for calls of £1 10*s.*	£1 5*s.* for every additional ¼ mile beyond 2 miles.
Message Rate. Outside County of London within two miles radius of Exchange.	£4	1*d.* per call to subscriber on same exchange, 2*d.* per call to subscriber on any other Exchange with minimum payment for calls of £1 10*s.*	do.
2 *Party Line.* Message Rate excepting Central Exchange	£3	As above, with minimum payment of £3	10*s.* for every additional ¼ mile.
10 *Party Line.* Any Exchange outside City	£2	As above, with minimum payment of £3	
Unlimited within two miles First line Each additional line	 £17 £14	 — —	£1 5*s.* for every additional ¼ mile beyond 2 miles.
Extension lines. In same premises less than 110 yards. Between separate premises not more than ¼ mile in length.	 £1 10*s.* £3 10*s.*	 — —	 For each additional 110 yards 10*s.* For each additional ¼ mile £1 5*s.*

TABLE 23.

PARTICULARS OF ACQUIRED NATIONAL TELEPHONE EXCHANGES OF 300 LINES AND OVER, WITH THE DIFFERENT SYSTEMS OF SWITCHING AND NUMBER OF ASSOCIATED SUBSCRIBERS' EXCHANGE LINES AS AT FEBRUARY 10TH, 1912.

System.	Flat Switchboards.		Upright Switchboards.		Total number of Switchboards.	Total number of Subscribers' Lines.	Remarks.
	Number of Exchanges.	Total number of Subscribers' Lines.	Number of Exchanges.	Total number of Subscribers' Lines.			
Ring through System with Lamps	2 *	6,343	7 †	6,341	9	12,684	* Manchester and Dundee. † Glasgow and Hanley.
Self-restoring Indicators.	1 *	2,332	4 †	14,086	5	16,418	* Bank, London. † Belfast, Dublin, Bradford, and Avenue (London).
Call Wire System.	3	3,491	—	—	3	3,491	Dundee and Glasgow.
Hand-restored Indicators.	—	—	135	100,160	135	100,160	
Common Battery.	—	—	68	130,777	68	130,777	
Miscellaneous.	—	—	11	11,003 *	11	11,003	* Principally Magneto call and lamp clearing.
Total.	6	12,166	225	262,367	231	274,533	

TABLE 24.

NUMBER OF EXCHANGE SUBSCRIBERS' LINES CONNECTED TO THE DIFFERENT SWITCHING SYSTEMS IN THE UNITED KINGDOM. EXCHANGES WITH 300 SUBSCRIBERS AND OVER ONLY, 1912–1924.

Date.	Call Wire System.	Ring through System with Lamps.	Hand-restored Indicators.	Self-restoring Indicators.	Common Battery System.	Automatic System.	Miscellaneous.	Total.
May 3, 1913	2,662	11,766	100,020	12,629	215,468	—	13,374	355,919
Jan. 31, 1914	2,655	10,894	101,174	12,687	230,094	—	13,907	371,411
1915–1918	No figures available for period of the war.							
May 3, 1919	—	8,873	90,048	11,556	247,183	14,358	11,602	383,620
May 1, 1920	—	9,569	99,045	12,695	274,879	16,607	11,720	424,515
May 7, 1921	—	9,995	99,152	12,829	301,453	17,609	12,012	453,050
April 29, 1922	—	7,849	93,064	8,006	323,356	17,682	12,382	462,339
April 28, 1923	—	7,699	90,756	7,407	366,849	18,880	13,075	504,666
May 3, 1924	—	3,841	103,077	5,615	421,542	26,469	8,958	569,502

APPENDICES

APPENDIX A

Early Telephone Testimonials

Five testimonials selected from eighteen letters included in a list of telephone subscribers issued by the Telephone Co., Ltd., bearing date April 26th, 1880.

From Sir Wm. Thomson, F.R.S., LL.D., M.S.T.E.

The University,
Glasgow,
May 23rd, 1879.

Dear Professor Bell,

I am sorry I have not been able to write to you sooner to tell you how very useful I find the Telephones which you so very kindly sent me. I have them fitted up as a means of communication between my house and my laboratory, and between my laboratory and the workshop of Mr. White, my instrument maker, in Sauchiehall Street. On the latter circuit I have found them of the greatest service. By their aid I have been able to interrogate Mr. White as to the progress of work in his hands, to advise him when difficulties occurred, to give him directions as to points of detail which otherwise might have been passed over, and even to describe fully to him a new instrument, and almost always I found that he had quite understood me. A great deal of time has thus been saved to me which otherwise would have been consumed in travelling between Mr. White's workshop and the University.

Believe me,
Yours very truly,
(*Signed*) WILLIAM THOMSON.

Davis's Wharf,
Tooley Street,
London, S.E.,
7th April, 1879.

The Secretary,
The Telephone Company.

Dear Sir,

We have much pleasure in testifying to the great benefit which your Telephones have been to us as a means of communication between our Wharf and City Office in Billiter Square, a distance by wire of about one and a half miles. They have been in constant use since June last, and we have found them work to our entire satisfaction. We have pleasure in recommending them.

We are, dear Sir,
Yours faithfully,
(*Sd.*) WILLIAMS, BROWN & ELMSLIE.

Midland Railway Telegraph Dept.,
Superintendent's Office,
Derby,
28th April, 1879.

Dear Sirs,

In reply to your enquiry of the 25th inst., I have the pleasure to inform you that the Telephones which have been erected on the Midland Railway are working very satisfactorily.

Yours faithfully,
(*Sd.*) W. LANGDON.

The Telephone Co.,
36 Coleman St.,
London, E.C.

Marlborough Works,
Marshall St.,
London, W.,
October 13th, 1879.

Dear Sir,

In reply to your letter of the 30th ult., we have the pleasure to inform you that the Telephones which have been in constant use for the last 2 years, between this place and our Haymarket House, have given and continue to give us the greatest satisfaction.

For 10 years prior we used the A B C Telegraph, but the trouble of having to transmit words, letter by letter, and the length of time so occupied, limited very much its frequent use.

By means, however, of the Telephone, messages pass to and fro almost continuously, averaging over 100 daily; we only had one break down, and that was during a heavy fall of snow the year before last when the overhead wire gave way.

We can scarcely understand how any house of business having two establishments can do without the Telephone.

We are now fixing several pairs in the new Municipal Bldgs. at Birmingham, one a central station communicating with two others, which we shall accomplish with only a single pair of instruments in the centre, in the same way as the Telegraph.

Those we supplied to Her Majesty at Windsor Castle and Buckingham Palace, also work satisfactorily.

For large buildings in the Country, from the Lodge to the House, in County Asylums, Hospitals, etc., we shall consider them invaluable.

We beg to remain, dear Sir,
Yours faithfully,
(*Sd.*) ADAMS & SON.

B. Saunders, Esq.,
36 Coleman St., E.C.

Winifred House,
Clifton,
Bristol,
19th Decr., 1879.

To the Telephone Company.

I have much pleasure in stating that I have had considerable experience of the Bell Telephones, and other apparatus supplied by the Telephone Co., Ltd., and that I consider them very satisfactory.

My own firm (Christopher Thomas & Brothers, Broad Plain Soap & Candle Works, Bristol) has had eight Hand Telephones in work for several months over 4 separate circuits in the factory and offices, where they are in hourly use, and save a great deal of time in the conveyance of Messages over distances where a speaking tube cannot be heard. The simplicity of these instruments is such that it is almost impossible for them to get out of order, and they may

be used at once with the greatest facility by clerks, foremen, and other persons, without any special training.

During a recent somewhat extended tour in the United States I had abundant opportunities of seeing the enormous facilities given to the conduct of business in large towns through the medium of the Telephonic Exchange, and I had the special advantage of examining the apparatus used, and the working of the whole system in Boston, under the guidance of the Inventor, Professor Alexander Graham Bell.

I have inspected and carefully tested the Apparatus now in work in the Bristol Telephonic Exchange. It appears to me to be precisely similar to some of the forms of apparatus now in use in America, and to be well adapted for the ends in view. I think so well of it that my own firm has joined the Exchange, and a wire is being carried to my residence in Clifton, in order to put me (through the central office of the Exchange) in direct communication with the works.

I have recommended the use of Telephones to many of my friends and, as a member of the Council of University College, Bristol, have promoted a private line between the College premises and the residence of the Principal.

On many grounds, both purely scientific and practical, I consider the Bell Telephone system to be the one best adapted to ordinary business purposes. The Exchange system is as yet in its infancy in England, but its development in the United States has been almost incredibly rapid; in some instances 1 per cent. of the whole population of a town being members of the Exchange. No one can form an idea of the variety of uses to which Telephonic communication can be put, until he has had a few weeks' experience of a Telephone in his office or house.

(*Sd.*) WM. LANT CARPENTER,
B.A., B.Sc. Lond., F.C.S.

APPENDIX B

Copy of a Draft of the Form of License First Issued to the Early Telephone Companies

THIS INDENTURE made the day of 188 Between THE RIGHT HONOURABLE HENRY FAWCETT Her Majesty's Postmaster General (who and his successors in office for the time being are intended to be hereinafter included in the term " the Postmaster General ") on behalf of Her Majesty of the one part and THE COMPANY LIMITED the registered office of which is at No.
(hereinafter called " the Company ") of the other part.

WHEREAS under or by virtue of the Telegraph Acts 1863 to 1878 and the Acts of Parliament Charters Grants and Agreements therein referred to and of divers conveyances awards and assurances executed in pursuance of the said Acts or some or one of them the Postmaster General has power to construct and work telegraphs and to grant Leases and Licenses and enter into agreements of and with respect to telegraphs and telegraph undertakings and the working and using thereof.

AND WHEREAS the Company have been formed for the purpose amongst other things of carrying on the business of constructing manufacturing maintaining working and using telegraphs and telegraphic apparatus concerned or intended to be connected with offices of the Company commonly known as Exchanges and of permitting and aiding in the working and user of such telegraphs and apparatus as aforesaid by such persons as the Company shall agree with in that behalf in manner hereinafter appearing on a system commonly known as the Exchange System and of selling and letting on hire such telegraphs and apparatus as aforesaid to such persons as aforesaid for the purposes of such working and user as aforesaid.

AND WHEREAS the said business is commonly known as the Exchange business of the Company and by reason of the provisions of the said Acts the same cannot be carried on without the License or sanction of the Postmaster General.

AND WHEREAS the Company are desirous of carrying on the said Exchange business in manner hereinafter authorised in the in the County of and in order to enable them so to do the Postmaster General has agreed to grant to the Company the Licenses powers and authorities hereinafter expressed and contained for the period upon the terms and subject to the stipulations and conditions hereinafter appearing.

NOW THIS INDENTURE WITNESSETH that in consideration of the premises and of the matters herein appearing it is hereby agreed and declared between and by the parties hereto and the Company (as to the covenants and agreements hereinafter contained on their part) do hereby covenant and agree with the Postmaster General and the Postmaster General (as to the covenants and agreements hereinafter contained on his part) in exercise of all powers and authorities enabling him in this behalf doth hereby covenant and agree with the Company in manner following that is to say :—

Interpretation clause.

1. (1) In these presents the following words and expressions shall have the several meanings hereinafter assigned to them unless there be something either in the subject or context repugnant to such construction that is to say :—

The word " Exchange " means and includes any building telegraphically connected or intended to be so connected with the offices as hereinafter defined of two or more subscribers as hereinafter defined by telegraph wires and used or intended to be used by the Company for the purpose of enabling telegrams to be transmitted between two or more of such subscribers by means or with the aid of such wires and of telegraphic appliances placed in the Exchange.

The expression " Exchange Telegraph " or Exchange Telegraphs " means and includes all or any telegraph wires telephones and other telegraphic transmitting and receiving instruments batteries switchboards switches and other telegraphic apparatus contrivances and appliances (except as hereinafter mentioned) in the possession of the Company or supplied by the Company to subscribers and used or intended to be used for the purpose of enabling telegrams to be transmitted between any two subscribers by means or with the aid of telegraphic appliances placed in an Exchange.

The word " office " means any building or part of a building or any other place (occupied or used by a subscriber in connection with his business or private affairs) where a telegraphic transmitting instrument and a telegraphic receiving instrument are or are intended to be fixed or placed to the intent that the same may be telegraphically connected with an Exchange either permanently or from time to time by means of Exchange Telegraphs.

The word " Subscriber " means any person entitled by permission of the Company testified by a certificate (hereinafter called a certificate of permission) under the hand of the Secretary of the Company to use at the office or offices specified in such certificate the said Exchange Telegraphs for the purpose of transmitting and receiving such telegraphic communications as hereinafter authorised.

The word " Person " includes any corporation and any joint stock company and any number of persons carrying on business in partnership but not any other association or aggregate of individual persons.

(2) Any office specified in the certificate of permission of a

subscriber shall for the purpose of these presents be deemed to be an office of such subscriber although it may be specified in the certificate of permission of and may be an office of any other subscriber.

(3) The Certificate of permission of a subscriber shall specify the period during which and the office or offices at which such subscriber shall be permitted to use the said Exchange Telegraphs and shall be in the form or to the effect set forth in the Schedule hereto as nearly as the nature of the case will admit or in such other form or to such other effect as shall from time to time be agreed upon between the Postmaster General and the Company.

License to Company to carry on Exchange business.

2. The Company shall during the term of 31 years commencing on or as from the 1st day of January 1881 (determinable nevertheless as in this Indenture provided) have License and permission from the Postmaster General to establish one or more Exchange or Exchanges as the Company may think fit within a radius of miles from a central point in aforesaid and such central point shall be the present Head Post Office in aforesaid unless the Company by notice in writing to be served on the Secretary of the Post Office within one calendar month after the date of this Indenture select some other central point aforesaid to be specified in such notice in which case the central point specified in such notice shall be the central point from which the said radius of miles is to be measured. And the Company shall have license and permission within the said radius of miles from such central point to work and use Exchange Telegraphs connecting such Exchanges if more than one with each other and also connecting such Exchange or Exchanges respectively with offices of subscribers situate within a radius of miles from such central point and to permit and aid in the use of the said Exchange Telegraphs by subscribers or their servants or agents on their behalf but not by any other person or persons for the purpose of enabling any subscriber or his servants or agents on his behalf to transmit direct from and to receive at any office of such subscriber to or from any office of any other subscriber telegrams relating to the business or private affairs of such subscribers or one of them and for the purpose of transmitting service messages in either direction between such Exchange or Exchanges and any subscriber's office relating to the establishment from time to time of telegraphic connection by means of switch-boards or other contrivances fixed or placed in such Exchange or Exchanges between such office and an office of any other subscriber or to the working or repair of the said Exchange Telegraphs and the Company shall have license and permission to receive from subscribers such sums of money for or in respect of the purchase or hire or maintenance or working of the said Exchange Telegraphs or any part or parts thereof or for or in respect of the right or permission to transmit such telegrams as aforesaid by means of the said Exchange Telegraphs or otherwise in respect of telegrams transmitted by means of the said Exchange Telegraphs as shall be agreed upon between the Company and the said subscribers respectively.

Certain wire and telegraphic apparatus not to be used for Exchange purposes.

3. The Company shall not at any time without the previous consent in writing of the Postmaster General use or permit to be used as an Exchange Telegraph or otherwise for the purposes of any of the Licenses powers or authorities hereby granted any telegraph wire or telegraphic apparatus or appliance which has been supplied to or has come into the possession of a subscriber otherwise than by purchase hire or loan from the Company or in respect of which or of the purchase or hire or maintenance or working or user or right of user of which any money or other

valuable consideration has been given or agreed to be given to the Company before the execution by them of these presents or after the execution thereof and before such wire apparatus or appliance was telegraphically connected with the Exchange Telegraphs for the time being of the Company and until such consent has been given no such wire apparatus or appliance as aforesaid shall be deemed to be an Exchange Telegraph within the meaning of these presents anything hereinbefore contained to the contrary notwithstanding.

Exchange Telegraphs to be used by Subscribers only.

4. The Company shall not at any time without the previous consent in writing of the Postmaster General permit any person not being a subscriber or a servant or agent of a subscriber on his behalf to transmit or receive any telegram by means of an exchange Telegraph or permit any subscriber or any servant or agent of a subscriber on his behalf to transmit or receive any telegram by means of the said Exchange Telegraphs otherwise than from or at an office specified in the Certificate of permission for the time being held by each subscriber.

Royalties.

5. In addition to all other moneys which may become payable to the Postmaster General under these presents the Company shall pay to the Postmaster General the following moneys hereinafter called royalties (that is to say) :—

(1) The Company shall pay to the Postmaster General a royalty equal to 10 per cent. of the gross amount of every sum of money paid or payable by any subscriber to or on behalf of the Company for or in respect of the purchase or hire or maintenance or working or user or right of user of any Exchange Telegraph or Telegraphs or any part or parts thereof or otherwise in respect of telegrams transmitted by means of any Exchange Telegraph or Telegraphs or otherwise howsoever in relation to any Exchange Telegraph or Telegraphs or any part or parts thereof and whether such sum of money is a gross sum or is payable periodically or by instalments and every such royalty shall become due so soon as the sum of money in respect of which it is payable or by the amount of which it is regulated shall be paid or shall by virtue of any express or implied contract or otherwise be payable whichever event shall first happen and shall for the purposes of these presents be deemed to be payable in respect of the user by such subscriber of the said Exchange Telegraphs at the office in relation to which such sum of money is paid or payable by him and if such sum of money is an aggregate sum paid or payable in relation to two or more offices the same shall if necessary for the purposes of these presents be apportioned among and be deemed to be paid or payable in relation to such offices respectively in such proportions as the Postmaster General shall think fit.

(2) In case any subscriber should give to or confer upon the Company any valuable consideration or benefit (not being money or a contract solely for the payment of money) for or in respect of the purchase or hire or maintenance or working or user or right of user of any Exchange Telegraph or Telegraphs or any part or parts thereof or otherwise in respect of telegrams transmitted by means of any Exchange Telegraph or Telegraphs or otherwise howsoever in relation to any Exchange Telegraph or Telegraphs or any part or parts thereof the Company shall pay to the Postmaster General a royalty equal to 10 per cent. of the value in money of such consideration or benefit and for the purpose of estimating the amount of such last-mentioned royalty the value in money of such consideration or benefit shall be determined by the certificate of such officer of the Post Office as the Postmaster General shall appoint for that purpose and such certificate shall be conclusive evidence of such value and such royalty shall be payable and paid at such time or times

and by such instalments and generally in such manner as the Postmaster General shall appoint and shall be payable in addition to such royalty or royalties (if any) as shall be payable in respect of such subscriber under the stipulations hereinbefore contained.

(3) In case the Company shall during any year permit the said Exchange Telegraphs to be used at any office by a subscriber whether in common with other subscribers or not and no royalty or a royalty less than one pound shall become due during such year under the stipulations hereinbefore contained in respect of such user at such office by such subscriber the Company shall for every year in which the same shall happen pay to the Postmaster General in respect of the user of the said Exchange Telegraphs at such office by such subscriber a royalty of One pound which shall become due on the 31st day of December in such year PROVIDED ALWAYS that there shall be deducted from the amount of the last-mentioned royalty the amount of such royalty or royalties (if any) as shall become due during such year under the stipulations hereinbefore contained in respect of such sum or sums of money (if any) as shall be paid or payable by such subscriber in respect of the user by him of the said Exchange Telegraph at such office during such year.

Revision of royalties.

6. The Postmaster General may if he shall think fit by giving six calendar months' previous notice in writing to the Company require that the amount of the royalties payable by the Company under these Presents shall be revised on or as from the 1st day of January 1891 the 1st day of January 1898 or the 1st day of January 1905 or on or as from any two or more of the said dates and such revision shall take place accordingly and any difference between the Postmaster General and the Company as to such revision shall be determined by arbitration in manner hereinafter provided subject to the condition that the amount of the Royalties as specified in these presents shall not in any case be reduced without the consent of the Postmaster General.

List of Subscribers and particulars of terms of subscription to be kept by the Company.

7. The Company shall at all times keep at their Chief Office or Exchange a book or books in which they shall enter the names addresses and occupations of all subscribers for the time being and the localities and other particulars of all offices specified in their respective certificates of permission and the sums of money if any from time to time paid and agreed to be paid respectively by such respective subscribers whether before or after the execution of these presents and the date at which every sum of money was paid or became payable and the nature of the consideration for the payment thereof and the particulars of every or any other valuable consideration or benefit given to or conferred upon or agreed to be given to or conferred upon the Company by any subscriber or respective subscribers whether before or after the date of these presents and the dates of and the names of the parties to all contracts in relation to the matters aforesaid or any of them and all such other particulars as the Postmaster General shall from time to time reasonably require and shall preserve at their Chief Office or Exchange all contracts between the Company and subscribers and duplicates or copies of all certificates of permission given by the Company to subscribers and the Postmaster General and his officers may from time to time and at all reasonable times inspect such book or books contracts and other documents and make copies thereof and extracts therefrom.

And to be supplied to Postmaster General monthly.

8. The Company shall within seven days after the expiration of every calendar month render to the Postmaster General a statement in writing containing a list of all subscribers to whom certificates of permission have been given during such calendar month with the particulars of every such certificate and showing the amounts of all sums of money and the nature of all other

considerations and benefits which during such calendar month have been paid or become payable or been given or conferred by subscribers or any of them on which have either before or since the execution of these presents been paid or become payable or been given or conferred in respect of any telegraph wires or other telegraphic apparatus or appliances which during such calendar month have become Exchange Telegraphs together with the name of the subscriber in each case and the date on which every sum of money was paid or became payable and on which every such consideration or benefit was given or conferred and the nature of the consideration given by the Company in each case and such further particulars as the Postmaster General shall from time to time reasonably require.

Accounts between Company and Postmaster General to be settled quarterly.

9. All accounts between the Postmaster General and the Company shall be settled quarterly up to the 31st day of March the 30th day of June the 30th day of September and the 31st day of December in every year and the account for each quarter of a year shall be rendered by the Company to the Postmaster General within 14 days after the expiration of such quarter and the balance due to the Postmaster General in respect of any quarter of a year shall be paid by the Company to the Postmaster General within 28 days after the expiration of such quarter.

Limit of area within License.

10. The Company shall not without the consent in writing of the Postmaster General either directly or indirectly establish or permit to be established telegraphic connection between any Exchange and any office building or place situate at a distance of more than miles from the said central point.

Restriction on nature of telegram to be sent over Exchange Telegraphs.

11. Except with the License or consent in writing of the Postmaster General neither any Exchange nor any subscriber's office shall be used for the receipt collection or delivery of any telegrams except such service messages as are hereinbefore mentioned and neither any Exchange nor any subscriber's office nor any wire forming part of the said Exchange Telegraphs of the Company shall be used for the transmission of any telegram except such telegrams as are hereinbefore expressly authorised to be transmitted by means thereof and no money or other valuable consideration shall in respect of the receipt transmission or delivery of any telegram by means of any Exchange Telegraph be or be promised to be paid or given to any subscriber by any person whomsoever not being a subscriber and the Company shall in every agreement with a subscriber make due provision for the observance of this article.

Exchange Telegraphs not to interfere with Postal Telegraphs.

12. All telegraph posts wires and telegraphic appliances used or intended to be used as part of or in connection with the Exchange Telegraphs of the Company shall be so erected fixed placed and used as not either directly or by reason of the working or user thereof to interfere with the efficient or convenient maintenance working or user of any telegraph posts wires or telegraphic appliances of the Postmaster General which may from time to time exist on which it is probable that the Postmaster General may have occasion to risk of damage or to risk of interference with the efficient or convenient working or user thereof.

Removal of injurious Exchange Telegraphs.

13. In case any telegraph post wire or telegraphic appliance used or intended to be used as part of or in connection with the Exchange Telegraphs of the Company or the working or user of any such post wire or appliance shall in the opinion of the Engineer-in-Chief for the time being of the Post Office certified by writing under his hand from any cause whatever damage or interfere with the efficient or convenient maintenance working or user of any telegraph post wire or telegraphic appliance of the Postmaster General for the time being existing or expose any such post wire or appliance to risk of damage or to risk of interference with the efficient or convenient working or user thereof the

Company shall within 24 hours after service on them of a notice in writing by the Postmaster General complaining of such damage or interference or apprehended damage or interference either remove the post or posts wire or wires or telegraphic appliance or appliances complained of in such notice or refix and repair the same to the satisfaction of the Engineer-in-Chief for the time being of the Post Office and if the Company shall make default in so doing within the time aforesaid it shall be lawful for the Postmaster General to remove or repair the post or posts wire or wires or telegraphic appliance or appliances complained of in such notice and the Company shall on demand pay to the Postmaster General the cost of the refixing and repair of any telegraph posts wires or telegraphic appliances of the Postmaster General which shall have been damaged as aforesaid and the cost of any removal or repair by the Postmaster General of the posts wires and telegraphic appliances complained of in such notice or any of them.

Power to Postmaster General to inspect telegraphs at Exchange and Subscribers' offices.

14. The Postmaster General and his engineers and agents may from time to time and at all reasonable times enter upon any Exchange and upon any subscriber's office for the purpose of inspecting and may inspect the telephones and other telegraphic instruments and appliances fixed or being in such places respectively and the Company shall from time to time upon the request of the Postmaster General procure from any subscriber his consent to such entry and inspection so far as regards the office of such subscriber and the telephones and other telegraphic instruments and appliances fixed or being in such office and the Company shall also upon the like request cause any subscriber to produce his certificate of permission for the time being to the Postmaster General and his officers and permit him and them to inspect the same.

License not to be assigned.

15. None of the Licenses powers or authorities hereby granted to the Company shall be or be deemed to be assignable either at law or in equity and the Company shall not execute any deed or instrument purporting to assign under-let or otherwise dispose of or to agree to assign underlet or otherwise dispose of such Licenses powers and authorities or any of them.

Power to Postmaster General to purchase Exchange Telegraphs.

16. The Postmaster General may at any time by six calendar months' previous notice in writing terminating on the 31st day of December 1890 or on the 31st day of December 1897 or on the 31st day of December 1904 signify to the Company his intention to purchase the exchange business with respect to which this Agreement is entered into and if any notice is given the Company shall sell and convey and the Postmaster General shall purchase all the Exchange Telegraphs of the Company worked under the provisions of these presents and all the rights powers privileges works and other property of the Company appurtenant to or forming part of such exchange business and the particulars of the property to be comprised in and the price to be paid by the Postmaster General for such purchase shall in case of difference be determined by arbitration as hereinafter provided.

Company to sell telegraphic apparatus to Postmaster General.

17. The Company shall from time to time upon the request of the Postmaster General sell or procure to be sold and deliver or procure to be delivered to the Postmaster General as the absolute owner thereof free from all restrictions or conditions either as to the user thereof by the Postmaster General or his assigns licensees or bailees or otherwise and at such prices as hereinafter mentioned in that behalf and in such numbers or quantities as the Postmaster General shall from time to time require telephones and other telegraphic apparatus of the like kind as those from time to time or at any time or times hereafter used by the Company as part of or in connection with the said Exchange Telegraphs whether the same shall or shall not be actually

used by the Company at the time when such request is made.

Ascertainment of price.

18. The prices to be paid by the Postmaster General for such telephones and telegraphic apparatus as last aforesaid shall in case of difference be determined by Arbitration as hereinafter provided subject to the condition that in no case shall such price exceed the lowest price at which such telephone or telegraphic apparatus shall for the time being have been sold to any Person or Company.

Not to be a condition precedent of delivery.

19. The existence of any difference between the Postmaster General and the Company as to the price to be paid for any telephone or telegraphic apparatus to be supplied by the Company to the Postmaster General under these presents shall not delay the delivery of such telephone or telegraphic apparatus to the Postmaster General but the same shall without reference to the price to be paid for the same be forthwith delivered to the Postmaster General upon his serving upon the Company notice in writing requiring such delivery.

Company to license Postmaster General to manufacture telegraphic apparatus.

20. The Company shall from time to time upon the request of the Postmaster General grant or procure to be granted to him such Licenses as he shall require entitling him or any persons or companies on his behalf to manufacture telephones and other telegraphic apparatus in such numbers and quantities as he shall from time to time think fit in accordance with the specifications of any Letters Patent relating thereto respectively which shall at the respective dates of such Licenses belong to or be subject to the disposition or under the control of the Company or of any person or persons company or companies in trust for or on behalf of the Company in consideration of the payment by the Postmaster General of such royalties as hereinafter mentioned and the telephones and other telegraphic apparatus so manufactured shall belong to the Postmaster General as the absolute owner thereof free from all restrictions or conditions either as to the user thereof by the Postmaster General or his assigns licensees or bailees or otherwise and every such License shall contain all such provisions as shall be necessary or proper for giving effect to the stipulations aforesaid and shall be for the whole term of the Letters Patent to which it relates or under which it is granted or for such shorter term as the Postmaster General shall think fit.

APPENDIX C

Copy of a Draft of the Modified Form of License Issued to Various Telephone Companies.

THIS INDENTURE made the day of One thousand eight hundred and ninety- BETWEEN Her Majesty's Postmaster General (who and his successors in office for the time being are intended to be hereinafter included in the term "the Postmaster General") on behalf of Her Majesty of the one part and THE COMPANY LIMITED the registered office of which is at No. (hereinafter called "the Company") of the other part.

WHEREAS under or by virtue of the Telegraph Acts 1863 or 1878 and the Acts or Parliament charters grants and agreements therein referred to and of divers conveyances awards and assurances executed in pursuance of the said Acts or some or one of them the Postmaster General has power to construct and work Telegraphs and to grant leases and licenses and enter into agreements of and with respect to

Telegraphs and Telegraph undertakings and the working and using thereof.

AND WHEREAS the Company have been formed for the purpose amongst other things of carrying on the business of constructing manufacturing maintaining working and using Telegraphs consisting of wires telephones and other transmitting and receiving instruments and other telegraphic apparatus and of permitting and aiding in the working and user of such Telegraphs as aforesaid and of selling and letting on hire such Telegraphs as aforesaid for the purposes of such working and user as aforesaid

AND WHEREAS by reason of the provisions of the said Acts such part of the said business of the Company as is intended to be hereby licensed cannot be carried on without the license or sanction of the Postmaster General.

AND WHEREAS at the request of the Company and in order to enable them to carry on the said business in manner hereinafter authorised the Postmaster General has agreed to grant to the Company the licences powers and authorities hereinafter expressed and contained for the period upon the terms and subject to the stipulations and conditions hereinafter appearing.

NOW THIS INDENTURE WITNESSETH that in consideration of the premises and of the matters hereinafter appearing it is hereby agreed and declared between and by the parties hereto and the Company (as to the covenants and agreements hereinafter contained on their part) do hereby covenant and agree with the Postmaster General and the Postmaster General (as to the covenants and agreements hereinafter contained on his part) in exercise of all powers and authorities enabling him in this behalf doth hereby covenant and agree with the Company in manner following that is to say :—

Interpretation Clause.

1. In these presents the following words and expressions shall have the several meanings hereinafter assigned to them unless there be something either in the subject or context repugnant to such construction that is to say :—

The word " Telephone " means and includes any telegraphic transmitting or receiving instrument for the time being in the possession of the Company or supplied by them to any person or persons and used or intended to be used at any Office for the purpose of transmitting or receiving spoken messages or communications by means of electricity.

The word " Office " means any building or part of a building or any place which is telegraphically connected or intended to be connected either permanently or temporarily by a telegraph wire or telegraph wires with some other building part of a building or place (whether such buildings parts of buildings or places respectively be occupied or used by any person solely or jointly with any other person) and in which telephones are or are intended to be used for the purpose of enabling any person to transmit from and receive at such building part of a building or other place such telegraphic messages as are hereinafter authorised.

The word " person " includes the Company party hereto and also any Corporation and any Joint Stock Company and any other Association or aggregate of individual persons.

License to Company to carry on Telephone business.

2. The Company shall during the term of 31 years commencing on or as from the first day of January One thousand eight hundred and eighty one (determinable nevertheless as in this Indenture provided) have licence and permission from the Postmaster General (subject as hereinafter provided) to work and use Telegraphs of which the transmitting and receiving instruments shall be telephones but no other kind or description of Telegraphs for the purpose of enabling any person with whom the Company agree in that behalf to transmit direct from and receive at any office to and from any other person at any other office by means of spoken words (but not otherwise) and with the aid of such Telegraphs as aforesaid Telegraphic messages relating to the business or private affairs of such persons respectively or one of them

and the Company shall have license and permission to receive from all such persons as they shall agree with as aforesaid for or in respect of the purchase or hire or maintenance or working or use of the said Telegraphs or any part or parts thereof for the purpose aforesaid or for or in respect of the right or permission to transmit or receive or otherwise in respect of the transmission or receipt of such telegraphic messages as aforesaid by means of the said Telegraphs such sums of money or other valuable considerations as shall be agreed upon between the Company and the said persons respectively PROVIDED ALWAYS that the term "business" used in these presents shall not be construed or held to mean or include the business of collecting receiving or delivering messages or other communications transmitted or intended for transmission by Telegraph or any other business of a like kind.

No written messages to be conveyed.

3. Neither any office whether in the occupation of the Company or of any other person nor any such Telegraphs as aforesaid nor any part thereof shall be used by the Company or by any other person either on their behalf or by their permission for the transmission or receipt of telegrams or telegraphic messages of any kind except such spoken messages as are hereinbefore expressly authorised nor shall any office nor any part of any office in the occupation of the Company either solely or jointly be used by the company or any other person or be permitted or suffered by the Company to be used by any other person for the purpose of making any copy transcript memorandum or note of any message or communication or of the contents substance purport or effect of any message or communication received at such office by means of the said Telegraphs or any part thereof it being the express intention of these presents and of the licence and permission hereby given that no written message or communication or any written copy memorandum or note of any message or communication or of the contents substance purport or effect of any message or communication transmitted to any such last-mentioned office by means of the said Telegraphs shall be made or taken at or conveyed from any such last-mentioned office by any person whomsoever for any purpose whatsoever and the Company shall make due provision and take all necessary and proper precautions for the observance of the conditions contained in this clause by each and every person who may be from time to time or at any time entitled or permitted to use any office in the occupation of the Company or any part thereof of the said Telegraphs or any part thereof. PROVIDED NEVERTHELESS that nothing herein contained shall prevent either the sender or receiver of any spoken message from making a note or memorandum of the purport of such message for the purposes of the business or private affairs of such sender or receiver.

No messages to be collected or delivered.

4. No office whether in the occupation of the Company or of any other person shall be used by the Company or any other person for the collection or delivery of telegrams or telegraphic messages of any kind nor shall any written message or communication or any written copy memorandum or note of any message or communication or of the contents substance purport or effect of any message or communication transmitted to any office by means of the said Telegraphs be delivered from such office or any other office and no money or other valuable consideration shall in respect of the transmission or receipt of any telegraphic message by means of the said Telegraphs or any part thereof be or be promised to be paid or given to any person (other than the Company) entitled or permitted to use the said Telegraphs by any other person whomsoever and the Company shall take all necessary and proper precautions for the observance of this condition and shall in entering into every agreement with any person or persons in relation to the aforesaid business of the Company make due provision for the summary determination by the Company of such Contract or Agreement on breach of this condition by any such person or persons.

Provisions as to breach

5. In case any person or persons with whom the Company may make any Contract or Agreement in relation to the aforesaid business of the

Company or any part thereof or who may be for the time being permitted by the Company to use at any office the said Telegraphs or any part thereof for the purposes hereinbefore authorised shall at any time during the continuance of these presents as hereinbefore provided use any office or the said Telegraphs or any part thereof respectively for any purpose or by any means or in any manner other than as hereinbefore expressly authorised and according to the conditions hereinbefore declared the Company shall thereupon forthwith determine any such Contract or Agreement with or withdraw such permission from any and every such person so using such office or the said Telegraphs or any part thereof and if such office belong to or be occupied by such person either solely or jointly with any other person or persons the Company shall forthwith disconnect such office from any other office which is or may be telegraphically connected therewith by means of their aforesaid Telegraphs and the Company shall give notice forthwith to the Postmaster General of such determination of Contract or Agreement or withdrawal of such permission as the case may be together with full particulars of the reasons for the same and the Company shall not without the special license and authority of the Postmaster General re-establish the telegraphic connection of such office with any other office or enter into any other Contract or Agreement with such person in relation to their aforesaid business or permit him to use their said Telegraphs at any other office. of Conditions.

6. The Company shall not at any time use or permit or suffer to be used for any of the purposes of these presents or any of the licenses powers or authorities hereby granted any Telegraph of the kind or description hereby licensed or any part of any such Telegraph which has been supplied to or has come into the possession of any person otherwise than by purchase hire or loan from the Company or in respect of which or of the purchase or hire or maintenance or working or user or right of user of or permission to use which any money or other valuable consideration has been given or agreed to be given to the Company before such Telegraph or part of such Telegraph as aforesaid was telegraphically connected with the aforesaid Telegraphs of the Company or has been given or agreed to be given to any person other than the Company either before or after the execution of these presents unless and until the Company shall have given notice in writing to the Postmaster General of their desire to use such Telegraph or part of such Telegraph as aforesaid three clear days at least before the user thereof and until such notice has been given no such Telegraph or part of such Telegraph shall be deemed to be within the license and permission granted by these presents and from and after the expiration of such notice the Company may work and use such Telegraph or part of such Telegraph as aforesaid in the same manner as any other Telegraph or part of any Telegraph hereby licensed subject on the part of the Company to the payment of the royalty hereinafter mentioned in respect thereof and to the observance and performance of the several covenants and conditions herein contained affecting the same. Unlicensed telegraphs not to be used for Company's business.

7. In addition to all other moneys which may become payable to the Postmaster General under these presents the Company shall pay to the Postmaster General the following moneys hereinafter called royalties (that is to say) Royalties.

(1) The Company shall pay to the Postmaster General a royalty equal to 10 per cent. of the gross amount of every sum of money paid or payable by any person to or on behalf of the Company for or in respect of the purchase or hire or maintenance or working or user or right of user of or permission to use any Telegraph or Telegraphs of the kind or description hereby licensed or any part or parts of such Telegraph or Telegraphs or for or in respect of the user or right of user of or permission to use any office or part of an office occupied by the Company or otherwise in respect of telegraphic messages transmitted by means of any

such Telegraph or Telegraphs or otherwise howsoever in relation to any such Telegraph or Telegraphs or any part or parts thereof and whether such sum of money be a gross sum or be payable periodically or by instalments and every such royalty shall become due so soon as the sum of money in respect of which it is payable or by the amount of which it is regulated shall be paid or shall by virtue of any express or implied contract or otherwise be payable whichever event shall first happen.

(2) In case any person should give to or confer upon the Company any valuable consideration or benefit (not being money or a contract solely for the payment of money) for or in respect of the purchase or hire or maintenance or working or user or right of user of or permission to use any such Telegraph or Telegraphs or any part or parts thereof or for or in respect of the user or right of user of or permission to use any office or part of any office occupied by the Company either solely or jointly or otherwise in respect of telegraphic messages transmitted or received by means of any such Telegraph or Telegraphs or otherwise howsoever in relation to any such Telegraph or Telegraphs or any part or parts thereof the Company shall pay to the Postmaster General a royalty equal to 10 per cent. of the value in money of such consideration or benefit and for the purpose of estimating the amount of such last-mentioned royalty the value in money of such consideration or benefit shall be determined by the certificate of such officer of the Post Office as the Postmaster General shall appoint for that purpose or in case of dispute by arbitration as hereinafter provided and such royalty shall be payable and paid at such time or times and by such instalments and generally in such manner as the Postmaster General shall appoint and shall be payable in addition to such royalty or royalties (if any) as shall be payable in respect of such person under the stipulations hereinbefore contained.

(3) In case any sum of money be paid or payable to or other valuable consideration or benefit be given to or conferred upon the Company by any person or persons for or in respect of the purchase or hire or maintenance or working or user or right of user of or permission to use any Telegraph maintained or used solely for the transmission of telegrams which are by law excepted from the exclusive privileges of the Postmaster-General (hereinafter for brevity styled a "Private Telegraph") in addition to any sum of money paid or payable or other valuable consideration given to or conferred upon the Company by the same person or persons for or in respect of the purchase or hire or maintenance or working or user or right of user of or permission to use any Telegraph of the kind or description hereby licensed the Postmaster General may at his option apportion such sums or other valuable considerations respectively either in whole or in part between the said private Telegraph and such other Telegraph as aforesaid in such manner or in such proportions as he may deem fit and proper and thereupon such sums or other valuable considerations respectively as he shall apportion accordingly shall as between the Company and the Postmaster General for the purposes of these presents be deemed to be the sums or valuable considerations respectively paid or given by such persons as aforesaid in relation to such private Telegraph and such other Telegraph as aforesaid respectively in lieu of the sums or valuable considerations actually paid or given by such persons in relation to such Telegraphs respectively.

(4) In case the Company shall as hereinbefore provided use or permit or suffer to be used for any of the purposes of these presents or any of the licenses powers or authorities hereby granted any Telegraph of the kind or description hereby licensed

or any part of any such Telegraph which has been supplied to or has come into the possession of any person otherwise than by purchase hire or loan from the Company or in respect of which or of the purchase or hire or maintenance or working or user or right of user of or permission to use which any money or other valuable consideration has been given or agreed to be given to the Company before such Telegraph or part of such Telegraph as aforesaid was telegraphically connected with the aforesaid Telegraphs of the Company or has been given or agreed to be given to any person other than the Company either before or after the execution of these presents the Company shall pay to the Postmaster General such a royalty in respect thereof as under all the circumstances of the case shall be fair and reasonable and the amount thereof shall be determined by the certificate of such officer of the Post Office as the Postmaster General shall appoint for that purpose or in case of dispute by arbitration as hereinafter provided and shall be payable and paid at such time or times and by such instalments and generally in such manner as the Postmaster General shall appoint.

(5) Nothing herein contained shall entitle the Postmaster General to receive any royalties from the Company on any money or other valuable consideration received by the Company on the sale of any Telegraph or Telegraphs which the Company after such sale do not work or use under this license it being the intention of these presents that all royalties payable to the Postmaster General in respect of any such Telegraph or Telegraphs shall be paid by the person working or using the same Provided always that the Company shall seven days at least before any such sale of any such Telegraph or Telegraphs as last aforesaid deliver a notice in writing of such intended sale at the General Post Office in London and such notice shall contain the name address and occupation of the intended purchaser or purchasers of such Telegraph or Telegraphs and also full particulars of the offices intended to be connected by means thereof.

Accounts of Company's business to be kept by the Company.

8. The Company shall at all times keep all such books of account as the Postmaster General may from time to time reasonably require of and relating to their aforesaid business and their aforesaid Telegraphs (including all private Telegraphs worked or used by persons respectively entitled or permitted to use any other Telegraphs of the Company and also all Telegraphs sold by the Company which the Company after the sale thereof do not work or use as aforesaid) and all moneys and other valuable considerations received by them in respect thereof as aforesaid and such books of account shall contain all such particulars as the Postmaster General shall from time to time reasonably require and the Company shall preserve all vouchers of the said accounts and all Contracts and Agreements between the Company and all or any such persons as aforesaid respectively and the Company shall from time to time and at all reasonable times produce for the inspection of the Postmaster General and his officers at the chief office for the time being of the Company all or any such books accounts vouchers contracts agreements and other documents as aforesaid and all other books accounts vouchers contracts agreements and other documents in any way relating to any business carried on by the Company and the Postmaster General and his officers may make copies of and extracts from all or any of such books accounts vouchers contracts agreements and other documents.

Accounts to be furnished to Postmaster General quarterly.

9. The Company shall within 28 days after the 31st day of March the 30th day of June the 30th day of September and the 31st day of December in every year render to the Postmaster General a statement or statements of account in writing in such form or forms as the said

Postmaster General may from time to time require showing the amounts of all sums of money and the nature of all other considerations and benefits which from the date hereof or from the date up to which the last statement or statements of account if any shall have been rendered have been paid or become payable or been given or conferred by all such persons as aforesaid in respect of all the matters aforesaid or any of them respectively or which have either before or since the execution of these presents been paid or become payable or been given or conferred in respect of any telephones telegraphs (including such private telegraphs as lastly hereinbefore mentioned) or other telegraphic apparatus or appliances which from the date hereof or from the date up to which the last statement or statements of account if any shall have been rendered have been placed at any office or between any two offices together with all such particulars in each case as the Postmaster General shall or may from time to time require.

Payments to be made quarterly.

10. The Company shall pay to the Postmaster General within six weeks after the 31st day of March the 30th day of June the 30th day of September and the 31st day of December in every year the amount or amounts which shall be due to the Postmaster General in respect of the preceding quarter of a year.

Power to Postmaster General to inspect Telegraphs at all offices.

11. The Postmaster General and his Engineers and Agents may from time to time and at all reasonable times enter upon all or any office or offices in the possession or occupation of the Company either solely or jointly with any other person or persons respectively for the purpose of inspecting and may inspect the telephones and other telegraphic instruments and appliances fixed or being in such places respectively and the working and user of such Telegraphs respectively and the Company shall from time to time upon the request of the Postmaster General procure from any person permitted by them to use the said Telegraphs at any other office or offices which may be occupied by them either solely or jointly with any other person his consent to such entry and inspection so far as regards such office or offices of such person and the telephones and other telegraphic instruments and appliances fixed or being in such office or offices.

License not to be assigned.

12. The Company shall not assign underlet or otherwise dispose of the powers or authorities hereby granted or any of such powers or authorities without the consent in writing of the Postmaster General.

Company's Telegraphs not to interfere with postal Telegraphs.

13. All Telegraph posts wires and telegraphic appliances used or intended to be used as part of or in connection with the Telegraphs of the Company shall be so erected fixed placed and used as not either directly or by reason of the working or user thereof to interfere with the efficient or convenient maintenance working or user of any telegraph posts wires or telegraphic appliances of the Postmaster General which may from time to time exist or which it is probable that the Postmaster General may have occasion to erect place fix or use or to expose any such posts wires or appliances to risk of damage or to risk of interference with the efficient or convenient working or user thereof.

Removal of injurious Telegraphs.

14. In case any telegraph post wire or telegraphic appliance used or intended to be used as part of or in connection with the Telegraphs of the Company or the working or user of any such post wire or appliance shall in the opinion of the Engineer-in-Chief for the time being of the Post Office certified by writing under his hand directly or indirectly damage or interfere with the efficient or convenient maintenance working or user of any telegraph post wire or telegraphic appliance of the Postmaster General for the time being existing or expose any such post wire or appliance to risk of damage or to risk of interference with the efficient or convenient working or user thereof the Company shall within 24 hours after service on them of a notice in writing by the Postmaster General complaining of such damage or interference or apprehended damage or interference either remove the post or posts wire or wires or telegraphic appliance or appliances

complained of in such notice or refix alter or repair the same to the satisfaction of the Engineer-in-Chief for the time being of the Post Office and if the Company shall make default in so doing within the time aforesaid it shall be lawful for the Postmaster General to remove alter or repair the post or posts wire or wires or telegraphic appliance or appliances complained of in such notice and the Company shall on demand pay to the Postmaster General the cost of any removal alteration or repair by the Postmaster General of the posts wires and telegraphic appliances complained of in such notice or any of them.

Company to pay cost of repairing damage done to postal Telegraphs by their Telegraphs.

15. In case any telegraph post wire or telegraphic appliance of the Postmaster General shall be damaged or the efficient working or user thereof shall be wholly or partially interrupted or otherwise interfered with and the Engineer-in-Chief for the time being of the Post Office shall certify by writing under his hand that such damage interruption or interference has been caused directly or indirectly by any telegraph post wire or telegraphic appliance used or intended to be used as part of or in connection with the Telegraphs of the Company or by anything done by or on behalf of the Company in relation thereto the Company shall on demand pay to the Postmaster General all costs that shall be reasonably incurred by him in repairing such damage and in removing or altering such post wire or telegraphic appliance so as to restore the same to efficient working order and in adding thereto or substituting therefor either temporarily or permanently any other posts wires or telegraphic appliances if the said Engineer shall certify that such addition or substitution is reasonably required.

Provisions for determination of License on breach of contract.

16. In case any sum of money which ought to be paid by the Company to the Postmaster General under or by virtue of these presents shall be in arrear and unpaid for one calendar month after the time at which the same ought to be paid under or by virtue of the covenants herein contained or in case of any breach non-observance or non-performance by or on the part of the Company of any of the covenants (other than a covenant for the payment of money) or conditions herein contained and on the part of the Company to be observed and performed then and in any such case the Postmaster General may by writing under his seal revoke and determine the licenses powers and authorities hereinbefore granted and each and every of them and thereupon the said licenses powers and authorities and each and every of them shall absolutely cease determine and become void. Provided always that no such revocation or determination as aforesaid shall prejudice or affect any right of action or remedy which shall have accrued or shall thereafter accrue to either of the parties hereto under the covenants herein contained.

Power to Postmaster General to purchase Company's Telegraphs.

17. The Postmaster General may at any time by six calendar months' previous notice in writing terminating on the 31st day of December 1890 or on the 31st day of December 1897 or on the 31st day of December 1904 signify to the Company his intention to purchase the business of the Company with respect to which this Agreement is entered into and if any such notice be given the Company shall sell and convey and the Postmaster General shall purchase all the Telegraphs of the Company worked under the provisions of these presents and all the rights powers privileges works and other property of the Company appurtenant to or forming part of such business and the particulars of the property to be comprised in and the price to be paid by the Postmaster General for such purchase shall in case of difference be determined by arbitration as hereinafter provided.

Arbitration.

18. All matters which in pursuance of the stipulations hereinbefore contained are to be determined by arbitration shall be referred to and determined by the award or awards of a single Arbitrator pursuant to and so as with regard to the mode and consequences of the reference and in all other respects to conform to the provisons of the Common Law Procedure Act 1854 or any then subsisting statutory modification or re-enactment thereof for the time being in force and the Arbitrator on any such reference shall have power to examine witnesses upon

oath or affirmation or otherwise and either to fix settle and determine the amount of costs and expenses of and incidental to the reference and award to be paid by both parties or by either party or to direct the same to be taxed as between solicitor and client or otherwise or to be setted by any other person or persons and to direct and award when and by and to whom such costs and expenses respectively shall be paid and these presents shall be deemed to be a submission to arbitration within the last-mentioned Act or any such modification or re-enactment thereof as aforesaid and may upon the application of either party to any reference thereunder and without notice to the other of them to be made a Rule or Order of any Division of Her Majesty's High Court of Justice.

Agreement not to affect Postmaster General's rights.

19. Nothing in these presents contained shall prejudice or affect the right of the Postmaster General from time to time to establish extend maintain and work any system or systems of telegraphic communication (whether of a like nature to the aforesaid business of the Company or otherwise) in such manner as he shall in his discretion think fit neither shall anything herein contained prejudice or affect the right of the Postmaster General from time to time to enter into agreements for or to grant licenses relative to the working and user of Telegraphs (whether of a like nature to those worked and used by the Company or otherwise) or the transmission of telegrams in any part of the United Kingdom with or to any Company person or persons whomsoever upon such terms as he shall in his discretion think fit. And nothing herein contained shall be deemed to authorise the Company to exercise any of the powers or authorities conferred on or acquired by the Postmaster General by or under the Telegraph Acts or any of them.

Notices, etc.

20. Any notice request or consent (whether expressed to be in writing or not) to be given by the Postmaster General under these presents may be under the hand of any one of the Secretaries or Assistant Secretaries for the time being of the Post Office and may be served by sending the same by registered post letter to the Company addressed to them at their registered office and any notice to be given by the Company under these presents may be under their Common Seal or under the hand of their Secretary and may be served by sending the same by registered post letter addressed to the Secretary of the Post Office London.

IN WITNESS whereof the above-named Postmaster General hath hereunto set his hand and seal and the Company have caused their Common Seal to be hereunto affixed the day and year first above written.

APPENDIX D

The Administrative County of London

By-Laws—Overhead Wires

By-laws made by the London County Council in pursuance of the London Overhead Wires Act, 1891

(N.B.—The Act (see section 18) does not extend to any wire placed by any person for his private use over land belonging to him or in his occupation, which does not extend over any street, and is so constructed and placed that neither the wire nor any support thereof or attachment thereto would be liable to fall into any public street.)

In these by-laws :—

The expression "the Act" means the London Overhead Wires Act, 1891.

The expression " wire " has the same meaning as in the Act, except that it does not include any support or attachment.

The expression " cable " means any covered or insulated wire, of which the diameter to the outside of the covering exceeds twice the diameter of the bare wire, and where more wires than one are enclosed in the same covering or insulation, includes all such wires and covering, without reference to diameter.

General

(1) The Company shall deliver to the Council and the local authority full particulars of the material and gauge of the wires of the Company, and the nature and position of the several supports, and the length of span between the several supports. The Company shall also deliver to the Council a plan, on a scale of not less than 25 inches to the mile, showing the routes of such wires, and the position of the supports, or at their option shall cause the routes of such wires and the position of the supports to be marked upon a map to be supplied for the purpose at the office of the Council.

Existing Wires

(2) In the case of wires or supports existing at the date of the approval of these by-laws the Company shall comply with the requirements of by-law 1 within six months after that date.

New Wires

(3) In the case of new wires or supports placed after the date of the approval of these by-laws, the Company shall comply with the requirements of by-law 1 within one month after the placing thereof.

(4) A wire shall not be placed so as at any point to be at a less height above the ground than 20 feet, or where it crosses a street 35 feet, or at a less height above the roof of any building then 6 feet, except where it is brought into any building for use in that building, or is attached to a chimney or other part of a building in accordance with these by-laws.

(5) Every wire shall be supported at intervals not exceeding 115 yards unless permission in writing be obtained from the Council and the local authority for a longer span.

(6) Every support for a wire shall be of durable material, and properly stayed against forces due to wind pressure, change of direction of the wires, and unequal length of span; and all independent conductors and suspending wires shall be securely attached to the supports.

(7) The factor of safety for all stresses arising from the weight of conductors and suspending wires shall be at least four at a temperature of 22° F. The factor of safety for all other parts of the structures shall be at least ten, taking the maximum possible wind pressure against a support acting in a horizontal direction at 30 lbs. per square foot. No addition need be made for a possible accumulation of snow.

(8) Every support for a wire shall be marked in such manner to be approved in the case of each Company by the Council as to identify the Company to whom it belongs.

(9) Where a support is used for the wires of more than one Company, the Company owning the support shall be responsible for the support and the attachment of the wires thereto.

(10) No cable shall exceed one pound per lineal foot in weight; and every cable shall be carried by independent suspending wires and attached to the same by efficient slings.

(11) Every iron or steel wire, and every iron or steel support or attachment, shall be efficiently protected from oxidation.

(12) All poles erected on buildings as supports for wires, unless fixed through the roof, shall be carried on shoes or saddles properly protected from oxidation, and shall be efficiently stayed, so that in the event of a pole breaking it shall be impossible for it to fall into any street.

(13) Every wire, attached to a chimney, wall, or other part of a building, shall be efficiently supported by angle plates of iron or bronze or other device approved by the local authority.

(14) Every wire support and attachment shall be duly and efficiently supervised and maintained by the Company.

(15) No wire support or attachment shall be in such a condition that danger to the public using the streets may be apprehended therefrom, and the Company to whom any wire, support or attachment being in such condition belongs, shall be guilty of an offence against these by-laws.

(16) No wire support or attachment shall remain erected after it has ceased to be in use, unless the Company intend wthin a reasonable time to take it again into use, and give notice of such intention to the Council and the local authority.

(17) On reasonable notice being given by the Council or the local authority to the Company, access at all reasonable times for the purpose of inspection of the Company's wires, supports, and attachments shall be given or secured by the Company to the inspectors of the Council and the local authority.

PENALTIES

(18) Any Company or person failing to comply with any of these by-laws, or of the provisions of the London Overhead Wires Act, 1891, or delivering any particulars which to their or his knowledge are incorrect, shall be guilty of an offence against these by-laws, and shall be liable to a penalty not exceeding five pounds, and to a further penalty not exceeding forty shillings for each day during which such offence is continued after conviction thereof.

Sealed, by Order,
H. DE LA HOOKE,
Clerk of the Council.

Approved on behalf of the Board of Trade. (L.S.)

HENRY G. CALCRAFT,
Secretary.

29th July, 1892.

APPENDIX E

LIST OF SELECTED HISTORIC TELEPHONE EXHIBITS AT THE SCIENCE MUSEUM, SOUTH KENSINGTON. DECEMBER, 1922

Cat. No.	
M 1848.	Original Telephone Receiving Set by Edison.
M 4136.	Two Bell Telephone Receivers in Mahogany.
1913/222.	Original Hand Telephone (Earpiece Missing).
1913/226.	Telephone Receiver of form originally patented by S. Bidwell in 1882.
1914/754.	Ader Receiver. Double Pole.
1914/755.	Single Pole Receiver (Polished Mahogany).
1914/757.	Double Pole Receiver in Wooden Case and with reed diaphragm.
1914/758.	Double Pole Receiver. Flat pattern with wooden handles.
1915/186.	Ader Receiver with cylindrical wooden handles.
1915/187.	Ader Receiver with magnet ring and handle.
1915/188.	Four Single Pole Bell Telephone Receivers with Caps to protect terminals, green, red, brown, and black casings respectively.
1915/190.	Stanhope Receiver with parchment diaphragm.
1915/193.	Spoon Receiver of double pole type.
1915/194.	Single Pole Receiver. N. T. Co. Pattern No. 18519.
1915/198.	Double Pole Receiver with no permanent magnets and in wooden case.
1915/199.	Electrophone Stand with six Ader receivers.
1916/336.	Wall Instrument. Crossley Patent 354 with Crossley Transmitter.
1916/337.	Patent Membrane Single Pole Receiver.

Cat. No.	
1908/181.	Gower Bell Transmitter with Porcelain Mouthpiece.
1911/53.	Gurney's Telephone Transmitter.
1911/54.	Deckert's Granular Transmitter.
1914/765.	Wall Instrument. Consolidated Transmitter. Carbon Pellets.
1914/817.	Early Type of Bell Transmitter with membrane transmitter.
1914/759.	Moseley Transmitter mounted on case containing transformer.
1915/200.	Gower's Carbon Transmitter in Case with Induction Coil.
1915/202.	Moseley's Carbon Transmitter with Induction Coil.
1915/209.	Bible Shaped Box Electrophone with three Ader Receivers.
1915/238.	Mix and Genest Transmitters.
1916/49.	Swinton's Microphone Telephone Transmitter (1884).
1916/50.	Swinton's Experimental Microtelephone Transmitter (1885).
1922/141.	Experimental Microtelephone consisting of two gas carbon pencils hanging horizontally in contact with vertical gas carbon pencils.
1922/142.	Experimental microtelephone in sound box consisting of two small blocks of wood charcoal pressed upon each other by a spring.
1922/143.	Experimental microtelephone consisting of a carbon block pressed upon a steel rod by means of a rod.
1922/144.	Experimental microtelephone consisting of three blocks of wood charcoal pressed together by a spring.
1922/145.	Microtelephone consisting of two small tubes filled with (apparently) powdered graphite.
1922/146.	Microtelephone as above but consisting of but one tube.
1922/147.	Ditto but with means of adjusting contact pressure of the particles.
1922/150.	Experimental Microtelephone consisting of carbon pencils resting in carboncups.
1922/151.	Experimental Microtelephone consisting of two carbon pencils with knife edge contacts.
1915/253.	Wall Instrument with Blake Transmitter and trembler bell.
1914/262.	Wall Instrument with carbon pencil transmitter and with bristle damper.
1914/814.	Wall Instrument with Deckert Transmitter.
1915/201.	Wall Instrument with Mix and Genest's Carbon Transmitter (brush damper).
1915/208.	Wall Instrument with horizontal carbon transmitter.
1915/229.	Telephone Set with Edison's Electromotograph Receiver.
1915/222.	Early Bell's Double Pole Receiver and Transmitter set with trembler bell.
1914/779.	Crossley Magnetic Bell with generator.
1915/235.	Early Double Pole Telephone Set with magneto generator and clockwork call alarm.
1914/805.	McGregor Call Register with wall instrument and Blake transmitter.
1914/804.	McGregor Call Register with check bell.
1916/52.	Direct Intercommunicated Telephone Switchboard by Campbell Swinton, 1887.
1911/355.	The " G.F.A." Telephone Silence Cover.
1914/787.	Bennett's Patent Telephone Translator.
1916/54.	Facsimile of the telephone made in 1865 by S. M. Yeates, of Dublin (Improved Reiss Telephone).
1916/51.	Telephone Apparatus Set patented by A. A. Campbell Swinton in 1885.
1916/53.	Early Set of Telephone Apparatus constructed by Messrs Thieler and Son.
1862/127.	Specimen of 1857 Atlantic Cable.
1862/148.	Specimens of Submarine Telegraph Cables 1851/62 : Dover-Calais, Dover-Ostende, Spezzia-Corsica, Cromer-Hanover, Cromer-Denmark, Folkestone-Boulogne, Beachy Head-Dieppe.
1867/32.	Piece of Original Telegraph Line laid down by W. F. Cooke from Euston Square to Camden Town.
1876/1273.	Specimen of first telegraph line 1837.
1876/1340.	Specimen of first Underground telegraph Line 1818.
1892/78.	Specimen of Crampton's Dover-Calais telegraph cable laid 1851.

Cat. No.

1912/350. Specimen of Lands End-Scilly Islands Cable laid 1869.
1913/230. Specimen of first cable between Dover and Calais 1850.
1913/234. Specimen of early underground cable laid in London 1846.
1920/683. Three pieces cable mounted on a board showing early method of jointing.
1860/60. Gisborne and Smith's Insulator for Telegraph Wires.
1860/61. Vulcanite Insulator for Telegraph Lines.
1877/433. White Porcelain Insulator for Aerial Lines.
1884/184. Specimen of old Insulator for Aerial Lines.
1915/54. Brown Earthenware Single Shed Solid Insulator with hooks at top and grooved. Harloe's Patent.
1915/521. Buff Earthenware Double Shed Insulator with mushroom top.
1915/505. White Porcelain Double shed Insulator with adjustable oil cup.
1915/504. White Porcelain Insulator Single Shed with grooved top. Oil cup type.
1915/501. White Porcelain single shed insulator with galvanized iron hood by Siemens.

Historic Telephone Apparatus Preserved in the Museum of the Institution of Electrical Engineers

Receiver, single pole, permanent magnet.
,, ,, ,, ,, ,, (18 C).
,, ,, ,, ,, ,, (18 T).
,, ,, ,, ,, ,, American make.
Ader Receiver, double pole, permanent magnet (168 F).
Receiver, single pole, electro magnet, Silvertown make, 18.
,, ,, ,, permanent magnet, Grays key for operators 19A.
,, ,, ,, ,, ,, shackle ring missing, 18 F.
Ader Receiver, double pole, permanent magnet.
Receiver, single pole, permanent magnet, 148 F.
,, double ,, electro magnet, membrane diaphragm, 148 L.
Ader Receiver, double pole, permanent magnet, 168 H.
Receiver (Edison), electro chemical chalk, Ed. make, 294 A.
Hunnings Transmitter, granular carbon.
Receiver, single pole, electro magnet, membrane diaphragm, Equitable Tel. Co.'s make, 146 A.
Bell Telephone, double pole electro magnet, tubular core.
Improved English Mechanical Receiver, 3 coil electro magnet, membrane diaphragm, Globe Co.'s type, 148 T.
Receiver, double pole, permanent magnet, Electrophone, 295 A.
,, ,, ,, ,, ,, 148 J.
,, single pole, ,, ,, 20 A.
Transmitter, granular carbon, for suspending on switchboards, W. E. Co.'s make, 72 B.
Receiver, double pole, permanent magnet, W. E. Co.'s make.
,, single ,, electro magnet, membrane diaphragm, Globe Tel. Co.'s type.
Blake Transmitter, carbon button for suspending on switchboards, W. E. Co.'s make, 101 B.
Cox-Walker "Husband" Telephone Receiver, with *mica* diaphragm and stirrup armature, presented by E. Cox-Walker, M.I.E.E., of Darlington.
Receiver, Collier Marr, permanent magnet, 15 A.
Full-sized reproduction of the original Telephone invented in 1875 by Alexander Graham Bell. Presented by J. E. Kingsbury, Esq., 7th May, 1913.

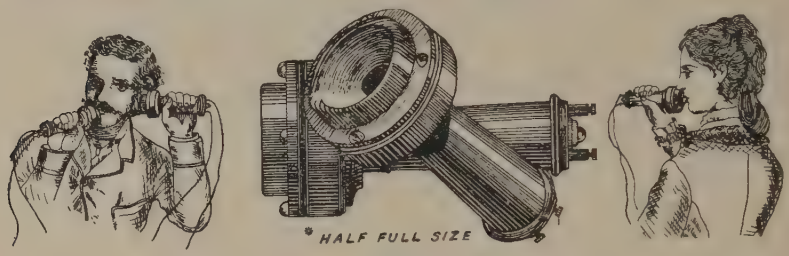
List of Specimens of Telephone Apparatus of Historic Interest Presented to the Institution of Electrical Engineers by the Author, February, 1923

1. Edison Telephone Instrument with Edison graphite transmitter and chalk receiver as employed by the Edison Telephone Co. of London, Ltd., in 1879.
2. 25-Line section Edison Peg Switchboard from the Edison Telephone Co.'s exchange in Queen Victoria Street, London, E.C.
*3. 6-Line Edison Peg Switchboard.
4. Early form of Ring Magnet Watch Receiver in ebonite case.
*5. Early form of Ader Receiver.
*6. Single Pole Receiver in polished mahogany case. One of the earliest made in this country.
*7. Two Single Pole Receivers employed in Sheffield by Messrs. Tasker and Sons, locally known as the "Potato Masher."
*8. Crossley Receiver in ebony case, invented by Mr. Louis John Crossley, of Halifax.
*9. Form of Single Pole Receiver much used at one time in this country.
*10. Stanhope Receiver.
*11. Early form of Double Pole Receiver used in this country.
12. Watch Receiver in mahogany case.
13. Single Pole Receiver employed in 1879 by the Telephone Company, Ltd., and bearing that Company's name on the earpiece.
14. Single Pole Receiver employed by the United Telephone Company, Ltd., and bearing that Company's name on the earpiece.
15. Single Pole Receiver employed by the National Telephone Company, Ltd., and bearing that Company's name.
*16. Transmitter of the Berthon type known as the "101 transmitter."
17. Blake Transmitter in nickel-plated metal case, employed for switchboards. The specimen was originally the property of the United Telephone Company and is stamped U.T. Co.
*18. Transmitter invented by Alexander Marr, of Manchester, and made by D. Moseley and Sons, Manchester.
19. Johnson Carbon Pencil Transmitter, invented by Mr. W. Johnson, of Sheffield, and employed by Messrs. Tasker and Sons, of that town.
*20. Marrs Inertia Transmitter (incomplete) as used by Mr. Charles Moseley for transmitting operatic and other music from Manchester theatres in 1880.
*21. Form of Telephone Instrument fitted with a Stanhope Transmitter.

* Presented to the Author by Mr. F. W. Best, of Rochdale.

APPENDIX F

REPRODUCTION OF A CIRCULAR ISSUED BY COLONEL REYNOLDS ON BEHALF OF PROFESSOR BELL IN THE LATTER PART OF 1877



THE TELEPHONE

The Articulating or Speaking Telephone of Professor Alexander Graham Bell has now reached a point of simplicity, perfection, and reliability such as give it undoubted pre-eminence over all other means for telegraphic communication. Its employment necessitates no skilled labour, no technical education, and no special attention on the part of any one individual. Persons using it can converse miles apart, in precisely the same manner as though they were in the same room. It needs but a wire between the two points of communication, though ten or twenty miles apart, with a Telephone or a pair of Telephones —one to receive, the other to transmit, the sound of the voice—to hold communication in any language. It conveys the quality of the voice so that the person speaking can be recognised at the other end of the line. It can be used for any purpose and in any position—for mines, marine exploration, military evolutions, and numerous other purposes other than the hitherto recognised field for Telegraphy; between the manufacturer's office and his factory; between all large commercial houses and their branches; between central and branch banks; in ship-building yards, and factories of every description; in fact wherever conversation is required between the principal and his agents or employés, or between the superintendent and his leading men, there the Telephone will find place and employment. Ordinarily it may be regarded as a speaking-tube attended with all the advantages of telegraphic communication.

TERMS

	Purchase.				Rental.			
	£	s.	d.		£	s.	d.	
For a set of Instruments for short circuits	25	0	0	or	5	0	0	per annum.
For a set of Instruments for long circuits	35	0	0	,,	10	0	0	,, ,,

Each set of Instruments consists of a pair of Telephones and a Call Bell—the equipment for one end of a communication.

Where required for Domestic purposes, Hotel, Factory, or other indoor uses, special rates will be quoted on application, stating the purposes for which the apparatus is required, with the distance between the points of communication.

A simple form of Agreement which those employing the instrument will be required to sign will be provided. In cases of rental this Agreement will be determinable at three months' notice, or, failing such notice, on the payment of such sum as the Agency may agree to accept in lieu thereof. The rental is in all cases payable in advance. The purchase-money paid for any set of instruments secures a Licence to use them only for the purposes specified within the Licence. The rental charge covers the cost of maintenance of the instruments hired. In either case the amounts specified cover all Royalty charges.

Further particulars and estimates may be obtained on application to the General Agent,

W. H. REYNOLDS,
12 *Queen Street, London, E.C.*

* The words "Half Full Size" have reference to the original circular, which is approximately twice the size of the reproduction.

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